Adv. Hort. Sci., 2019 33(4): 593-603 DOI: 10.13128/ahsc-8228

AHS
Advances in Horticultural Science

Effect of palm leaf biochar on melon plants (*Cucumis melo* L.) under drought stress conditions

S. Bagheri [1], M.R. Hassandokht [2 (*)], A. Mirsoleimani [3], A. Mousavi [4]

[1] *Department of Horticultural Sciences, Faculty of Agriculture, Tehran Science and Research Branch University, Tehran, Iran.*
[2] *Department of Horticultural Sciences, Faculty of Agriculture, University of Tehran, Karaj, Iran.*
[3] *Department of Plant Production, Faculty of Agriculture and Natural Resources of Darab, Shiraz University, Shiraz, Iran.*
[4] *National Institute of Genetic Engineering and Biotechnology, Tehran, Iran.*

OPEN ACCESS

Key words: macro-elements, melon, micro-elements, morphological traits, proline.

(*) **Corresponding author:**
mrhassan@ut.ac.ir

Citation:
BAGHERI S., HASSANDOKHT M.R., MIRSOLEIMANI A., MOUSAVI A., 2019 - *Effect of palm leaf biochar on melon plants (Cucumis melo L.) under drought stress conditions* - Adv. Hort. Sci., 33(4): 593-603.

Data Availability Statement:
All relevant data are within the paper and its Supporting Information files.

Competing Interests:
The authors declare no competing interests.

Received for publication 23 June 2019
Accepted for publication 24 October 2019

Abstract: In order to investigate the effect of palm leaf biochar on some characteristics of *Cucumis melo* L. under drought stress, a split plot experiment was conducted in a completely randomized block design with three replications for two consecutive years. The main plot was irrigation level (60, 85, and 100% water requirement) and subplot was biochar in four levels (0, 0.18, 0.24, and 0.36 kg/m^2). Results showed that treatment of 0.24 kg/m^2 biochar and 100% water requirement increased the characteristics of water use efficiency as 88%, shoot fresh weight as 77%, shoot dry weight as 32%, root fresh weight as 100%, root dry weight as 84%, root length as 54%, and average fruit weight 84% compared to treatment without biochar and 60% water requirement. The highest level of leaf N, Mn and K, shoot length, leaf area, leaf number, fruit diameter and fruit flesh thickness in the treatment of 0.36 kg/m^2 biochar and 100% water requirement were higher 58%, 48%, 65%, 18%, 50%, 95%, 43% and 55%, than to of treatment without biochar and 60% water requirement respectively and had no significant difference with the treatment of 0.24 kg/m^2 biochar and 85% water requirement. The highest rates of Fe, Zn and Cu were related to 0.36 kg/m^2 biochar and 60% water requirement as 60, 44 and 66% respectively compared to treatment without biochar and 100% water requirement. The biochar-free treatment with 60% water requirement accounted for the highest amount of proline due to high stress, and the proline content reduced with increasing biochar and decreasing stress in treatments. Generally, the treatments of 0.24 and 0.36 kg/m^2 of biochar increased most of the characteristics, however no significant difference was observed between these treatments. Moreover, in 85% water requirement the drought stress conditions could compensate with the application of biochar. Thus, using 0.24 kg/m^2 of biochar and 85% of water requirement, recommended for the best result.

1. Introduction

Melon (*Cucumis melo* L.) is from cucurbitaceae family that requires warm weather and high light to grow (Sangeetha *et al.*, 2006). Drought is one of the most important environmental stresses that adversely impact plant growth and crop production. More than 45% of world's agricultural lands are permanently exposed to drought and 38% of the world's population resides in those places (Ashraf and Foolad, 2007). Therefore, the majority of efforts will be focused on producing more crops in water shortage conditions in the future (Sinaki *et al*., 2007). In arid and semi-arid conditions, which consist of the major part of Iran, the lack of sufficient and proper vegetation causes reduction of the return of plant remnants and organic matter to the soil (Tate, 2000). Most of the soils in the arid and semi-arid areas in Iran contain less than 1% organic matter (Asghari, 2011). The organic matter shortage reduces the stability of the soil structure and its flaking, eventually creating a hard and dense soil (Hemmat *et al*., 2010). The use of organic fertilizers such as animal manure is a way of increasing the organic matter content in agricultural soils, however the application of this material cannot meet the needs of these soils (Mesa and Spokas, 2011). Therefore, in order to improving the soil, the use of organic resources such as agricultural waste, compost, urban waste, and sewage sludge is necessary, so that while increasing agricultural products, sustainable development can be achieved in agriculture (Yin Chan and Xu , 2009; Nazmi *et al*., 2012). In recent years, biochar has been used as a soil reformer, an organic carbon source, and somehow a method for carbon sequestration in agricultural soils. Biochar is a char produced from plant biomass and agricultural waste like wheat straw, corn, rice, which is produced during the thermochemical process of pyrolysis; this process is referred to the slow burning of organic matter under low or lack of oxygen condition (Glaser and Birk, 2012). It has been reported in several studies that biochar is a useful reformer to improve the soil physical and chemical characteristics and is effective in preserving soil organic matter, increasing fertilizer efficiency, and enhancing crop production, especially in the soils of subtropical and tropical areas that have long been cultivated (Van Zwieten *et al*., 2010). Biochar enhances the water holding capacity of the soil (Basso *et al*., 2013) and change the particle size distribution and porosity of the soil due to its high specific surface area (SSA) (Sun *et al*., 2014) and also is a direct source for K, Ca, P, Zn, and Cu (Chan *et al*., 2008). In addition, biochar increase the soil nutrient availability due to increasing the cation-exchange capacity (CEC), changing the soil pH. Using a biochar produced from rice plant residues increased the plant fresh and dry weight, root fresh and dry weight, stem length, and leaf number in lettuce and cabbage plants (Carter *et al*., 2013). Addition of biochar increased the soil pH, EC, organic carbon, CEC and N, P, K, Na, Ca, and Mg concentration of the soil and also the P, N, and K contents of the lettuce plants in this soil (Nigussie *et al*., 2012). Depending on the variety and farming conditions during the year, each palm produces about 15-25 dry leaves, each weighting 1.5 to 2.5 kg. The generalization of this amount of plant residues to several million palms in Iran leads to a great deal requiring the management of productivity and optimal use. These wastes can be converted into biochar and then used in soil. In recent years, many areas of Iran have been faced with water shortages and droughts, thus increasing soil water holding capacity by adding organic matter and biochar to soil can increase the potential of land use in these areas. Therefore, the present study was accomplished aiming to exploit the palm leaf biochar in order to increase soil organic matter and diminish the adverse effects of drought stress and investigate its effect on some characteristics of melon plants.

2. Materials and Methods

This experiment was carried out in 2016 and 2017 in an agricultural farm in Zarrindasht region of Fars province, Iran, with a longitude of 54°, 20' and a latitude of 28°, 20' with an altitude of 1021 m from the sea level. In this experiment, the Samsouri Varamin early variety melon was used. The remains of palm leaves from Zarrindasht orchards were collected, air dried, and crushed and then packed in aluminum sheets to limit the oxygenation and packs were placed in the oven for four hours at 560 °C to produce biochar (Hall *et al.,* 2008). Table 1 shows some chemical properties of biochar used in the experiment. This experiment was conducted in the split

Table 1 - Some chemical characteristics of biochar used in the experiment

pH (1:7)	EC (dS m^{-1}) (1:7)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Fe (ppm)	K (%)	P (%)	N (%)
9	7.5	0.74	0.09	0.83	983.2	32.4	2	1.39

plot form in completely randomized block design with three replications. The main plot was irrigation level in three levels (60, 85, and 100% water requirement) and biochar as subplot in four levels (0, 0.18, 0.24, and 0.36 kg/m^2).

I1B1 = Without biochar with 60% water requirement;
I1B2 = 0.18 kg m^2 biochar with 60% water requirement;
I1B3 = 0.24 kg m^2 biochar with 60% water requirement;
I1B4 = 0.36 kg m^2 biochar with 60% water requirement;
I2B1 = Without biochar with 85% water requirement;
I2B2 = 0.18 kg m^2 biochar with 85% water requirement;
I2B3 = 0.24 kg m^2 biochar with 85% water requirement;
I2B4 = 0.36 kg m^2 biochar with 85% water requirement;
I3B1 = Without biochar with 100% water requirement;
I3B2 = 0.18 kg m^2 biochar with 100% water requirement;
I3B3 = 0.24 kg m^2 biochar with 100% water requirement;
I3B4 = 0.36 kg m^2 biochar with 100% water requirement.

In the year before planting, the farm was fallow plowed well and leveled. Before planting, a soil sample prepared and some its chemical properties were evaluated (Table 2). Biochar was mixed with soil at 10 cm depth and then seeds were planted at an appropriate depth on the rows at distance of 2.5 m and 0.5 m on the row. The drip irrigation was applied, so that, a dripper was placed beside each plant in order to measure the amount of water consumed by the plant. In the 4 to 5 leaf stage, 50 kg/ha of nitrogen, 40 kg/ha of phosphorus and 40 kg/ha of potassium were added to the soil from sources of urea, potassium sulfate and Triple Super Phosphate respectively.

Table 2 - Some chemical characteristics of the farm soil

pH (1:7)	EC (dS m-1) (1:7)	N (%)	P (%)	K (%)
7.8	0.54	0.05	0.122	0.014

To estimate of the plant water requirement, the meteorological data including minimum and maximum temperature, minimum and maximum humidity, solar radiation, and wind speed were taken from the Zarrindasht Meteorological Office (Table 3). Then, the amount of evapotranspiration of melon plant was measured and the daily water requirement of the plant was obtained using the appropriate formulas for two years. For estimation of potential evapotranspiration parameters (ETOs) and water requirements by the proposed method of FAO using meteorological data and field surveys related to agronomic calendar and different stages of plant growth. It is then calculated by introducing the vegetation coefficient (Kc) according to plant type, stage and duration of growth and its effect on (ETO), evapotranspiration (ETc). Finally, by reducing the effective rainfall, the net requirement of irrigation water (In), which is the soil moisture deficiency, is estimated to be offset by irrigation.

Etc = Eto*Kc, where:

ETc = Actual evapotranspiration of the plant (mm/day)

ETo = Reference evapotranspiration (mm/day)

Kc = Plant coefficient.

Before the melon fruit ripens, parameters of stem length, plant length, leaf area, and number of leaves per plant were measured. At harvest time, the parameters of total yield, average fruit weight, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight determined by scale. Fruit length, fruit diameter and root length determined by a ruler and fruit skin thickness, fruit flesh thickness, determined by a caliper after slicing the fruits. Since it was not possible to separate the leaf at all stages to mea-

Table 3 - Some meteorological characteristics during the two years of experiment

Year	Month	Mean minimum temperature (°C)	Mean maximum temperature (°C)	Precipitation (mm)	Potential evapotranspiration (mm)
2016	Mar.	6.4	29.8	30	187.6
	Apr.	12.2	42.8	0.2	314.9
	May.	17.6	44.2	0	397.8
2017	Mar.	9.8	37.2	25.9	185.2
	Apr.	15.2	39.8	3.2	300
	May.	17.8	44.8	0	387.4

sure the leaf area, first several leaves were separated and their length, width, and length by width were calculated. Then, the area of the leaves was measured using the graph paper (mm) and the surface area relation was obtained using the Excel software. The following relation, which has the highest regression coefficient (R^2), was used to calculate the leaf area:

Y= 1.03 x + 44

where:

Y (cm^2) = Leaf area

X (cm^2) = Length (cm) * Width (cm)

Leaf proline content were determined by Bates method (Bates *et al.*, 1973). Leaf samples washed with distillated water, dried at 65°C for 48 h in an oven and ground. Total N in the leaves was determined by micro-kjeldahl method (Bremner, 1996). The grounded leaf samples were ashed at 550°C and digested with 2 N hydrochloric acid. P concentration in the extracts was determined by the yellow color method and K using flame photometer (Helmke and Sparks, 1996). Concentrations of Fe, Zn, Mn and Cu were determined by an atomic absorption spectrophotometer (PG 990, PG Instrument Ltd. UK) as well. The water use efficiency was calculated as a correlation between plant yield and plant water use during the treatment period (Liu *et al.*, 2015).

WUE = Y/V

Where: WUE, Y, and V were water consumption efficiency in kg/m^3, plant yield in kg per plant, and total water consumption in m^3, respectively.

Statistical analysis was performed using the SAS software (Statistical Analysis System) (V9) (SAS Institute Inc. Cary, NC, USA). Differences among the mean values were detected by Least Significant Differences (LSD) test at %5 level.

3. Results

The results revealed that the effects of drought stress and biochar and also the interaction of them were significant on water use efficiency and all physiological characteristics (Table 4). I3B3 and I3B4 treatments increased 88% and 76% in water use efficiency respectively compared to I1B1 treatment, however there was no significant difference compared to treatments of I3B2, I2B3 and I2B4 (Table 5).

Table 4 - Results of analysis of variance (ANOVA) of biochar on some properties of melon plants under drought stress

Source of changes	Degree of freedom	Mean square												
		Water use efficiency	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Shoot length	Root length	Leaf area	Leaf number	Fruit diameter	Fruit flesh diameter	Average fruit weight	Total yield
r (replication)	2	125.59	42833.5 *	3253.9 **	53.3 **	1.0 **	112.5 **	35.5 **	115.1	1626.1 **	10.2	0.07	60257.037 **	1506425.93 **
Stress (a)	2	103.08 **	228545.6 **	6954.6 **	158.6 **	2.9 **	184.2 **	72.8 **	4135.6 **	3603.2 **	351.9 **	2.5 **	597026.20 **	14925655.00 **
r (year)	2	5.69	9183.5	15.3	1.02	0.1	1.2	0.2	76.5	2.2	4.1	0.09	29931.55	748288.89
Biochar (b)	3	37.19 **	229634.7 **	3071.4 **	81.0 **	1.1 **	117.8 **	20.0 **	6129.9 **	3079.3 **	82.0 **	0.6 **	225506.06 **	5637651.49 **
a*b	6	7.44 **	59484.6 **	358.1 **	10.0 *	0.3 **	60.9 **	4.2 *	1087.7 **	618.2 **	25.5 **	0.15 *	38834.35 **	970858.94 **
a*r (year)	8	4.9	11845.3	367.0	4.0	0.1	28.5	2.3	608.7	47.4	6.3	0.2	18493.98	462349.70
Error	36	1.43	13001.4	69.7	4.19	0.0825	13.47	1.777	244.9	117.4	4.78	0.0561	5284.20	132105.19

Table 5 - Effects of biochar and drought stress on some properties of melon plants under drought stress

Treatment	Water use efficiency	Shoot dry weight (g)	Root dry weight (g)	Shoot length (cm)	Root length (cm)	Leaf area (cm^2)	Leaf number per plant	Fruit diameter (cm)	Fruit flesh thickness (cm)	Average fruit weight (g)
I1B1	7.19 c	188.3 e	1.71 d	75 d	10.2 e	167.7 d	76.5 e	36 e	2.15 e	565.2 d
I1B2	7.75 c	193.3 de	2.52 bc	77 cd	12.7 d	186.9 cd	91.5 de	43.3 d	2.76 cd	612.7 cd
I1B3	7.92 c	206 cd	2.34 bc	76.8 cd	13.4 cd	188.3 cd	103.4 bcd	43.3 d	2.64 d	624.6 cd
I1B4	7.88 c	205.2 cd	2.06 cd	77 cd	14.1 bcd	190.2 cd	106.5 bcd	43.4 d	2.84 bcd	637.5 cd
I2B1	7.68 c	200.8 cde	2.5 bc	77 cd	14.7 bcd	193.1 cd	98.5 cd	46.4 cd	2.81 bcd	603.7 cd
I2B2	8.73 bc	216 bc	2.68 ab	81.2 bcd	14.2 bcd	198.8 c	104.2 bcd	46.1 cd	2.83 bcd	687.9 cd
I2B3	11.77 ab	238.7 a	3.14 a	85.5 ab	15.8 abc	212.2 bc	119.7 ab	48.2 bc	3.23 ab	929.3 ab
I2B4	12.01 ab	209.8 bc	2.44 bc	79.6 bcd	15.2 abc	207.5 bc	110 bcd	46.5 cd	3.19 abc	934.7 ab
I3B1	9.02 bc	213.3 bc	2.77 ab	78.1 cd	14.5 bcd	202.4 c	103 bcd	47 c	3.14 abc	723.1 c
I3B2	12.01 ab	222.7 b	2.68 ab	80.8 bcd	15.9 abc	203.1 c	106 bcd	46.5 cd	3.16 abc	922.7 b
I3B3	13.55 a	250 a	3.15 a	83.4 abc	17.5 a	233.9 ab	117.4 abc	50.7 ab	3.3 a	1057 a
I3B4	12.69 a	249.2 a	2.71 ab	88.5 a	16.1 ab	252.7 a	132.5 a	51.7 a	3.35 a	994.7 ab

Interaction of the treatments indicated that the treatment of I3B3 increased shoot fresh weight (Fig. 1), shoot dry weight (Table 5), root fresh weight (Fig. 2), root dry weight and root length (Table 5) by 77, 32, 100, 84, and 71% compared to the treatment of I1B1, respectively. The highest shoot length, leaf area, leaf number per plant, fruit diameter, and fruit flesh thickness (Table 5) were associated with I3B4 treatment, which increased these characteristics 18, 50, 95, 43, and 55% compared to I1B1 treatment respectively and there was no significant difference compared to the I3B3 treatment. Regarding the shoot length, leaf number per plant, and fruit flesh thickness (Table 5), there was no significant difference between I3B4 treatment with the treatment of I2B3. The treatment of I3B3 increased the average fruit weight (Table 5) and total yield (Fig. 3) by 84% compared to the treatment of I1B1, however there was no significant difference compared to the treatments of I3B4 and I2B3 with increase rates of 73, 63, and 62%, respectively. The biochar-free treatment with 60% water requirement also accounted for the lowest rates in all characteristics. The results indicated that the effects of drought stress and biochar as well as the interaction of them on leaf proline content and all chemical characteristics except for the interaction of P were significant (Table 6). The treatment of I3B4 increased the N (Fig. 4), K (Fig. 5), and Mn (Table 7) as 58, 65, and 48%, respectively, compared to the treatment of I1B1. Regarding N ele-

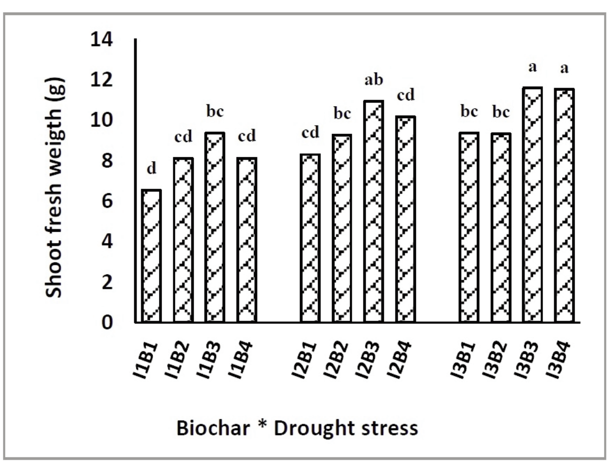

Fig. 1 - Effects of the interaction of biochar and drought stress on shoot fresh weight of melon.

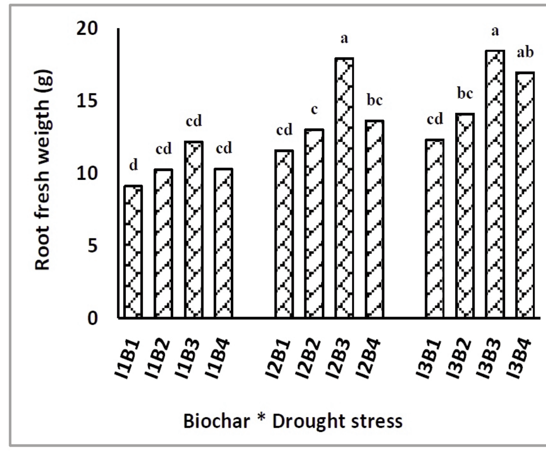

Fig. 2 - Effects of the interaction of biochar and drought stress on root fresh weight of melon.

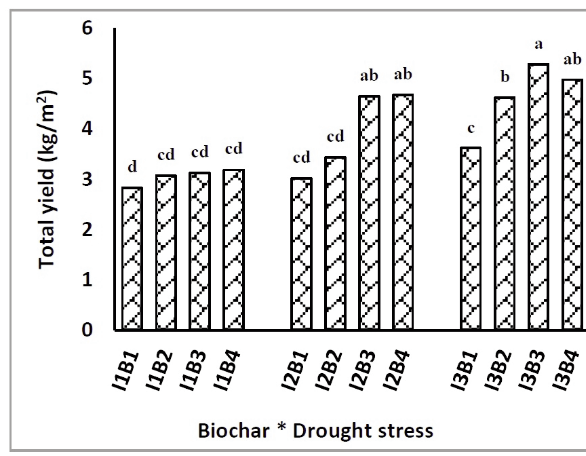

Fig. 3 - Effects of the interaction of biochar and drought stress on yield of melon.

Table 6 - Results of analysis of variance (ANOVA) of chemical characteristics of melon leaf

Source of variation	Degree of freedom	Mean square							
		N	P	K	Fe	Zn	Cu	Mn	Proline
r (replication)	2	1.0 **	0.004 *	0.2 *	3505.7 **	144.7 *	4	68.2 *	1.5 *
Drought stress (a)	2	3.1 **	0.06 **	2.1 **	14716.9 **	1321.4 **	24.9 **	970.7 **	166.2 **
r (year)	2	2.3	0.02	1.2	20.0	39.9	0.2	5.8	0.04
Biochar (b)	3	1.2 **	0.01 **	1.0 **	34202.0 **	836.3 **	63 **	363.5 **	13.7 **
a*b	6	0.3 **	0.008 NS	0.2 **	9413.6 **	184.6 *	11.8 **	200.9 **	2.2 **
a*r (year)	8	0.08	0.001	0.07	1356.1	46	0.66	53.2	2.5
Error	36	0.0734	0.00123	0.0446	623.32	76.479	3.135	15.31	0.528

* and ** indicate significant difference in 1 and 5% level respectively; NS= not significant.

ment, the treatments of 0.36, 0.24 and 0.19 Kg/m^2 and 100% water requirement was not significantly different in comparison to treatments of I2B3 and I2B4 (Fig. 4). In terms of K, there was no significant difference between the treatments of I3B3 and I3B4 (Fig. 5). In addition, the Mn content in the treatments of I3B3 and I3B4 was not significantly different in compared to I2B3 and I2B4 treatments and the lowest rate was also related to the biochar-free treatment with 60% water requirement (Table 7). The treatment of 0.36 Kg/m^2 increased the P level by 20% compared to the treatment without biochar and accounted for the highest rate, although it was not significant compared to the treatment of 0.24 Kg/m^2 (15%) (Figs. 6 and 7). Mean comparison of drought stress treatments suggested that 100% and 85% water requirement increased the leaf P content 36% and 10% compared to the treatment of 60% water requirement respectively and were significantly different compared to each other (Figs. 6 and 7). The

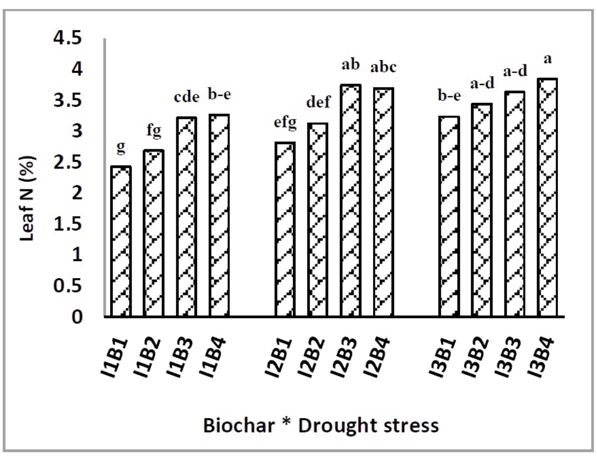

Fig. 4 - Effects of the interaction of biochar and drought stress on melon leaf N content.

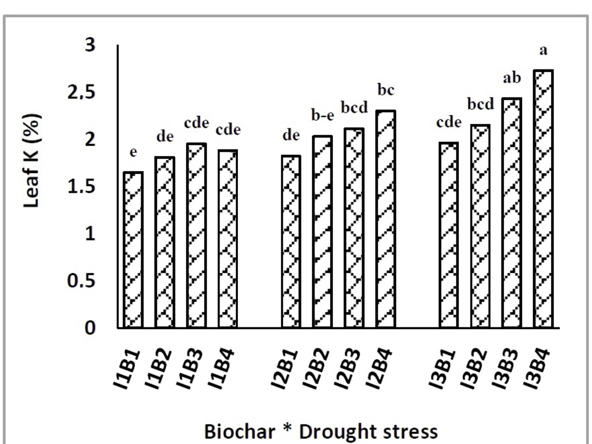

Fig. 5 - Effects of the interaction of biochar and drought stress on melon leaf K content.

interaction of drought stress and biochar treatments showed that the treatment of 0.36 Kg/m^{2}and 60% water requirement increased leaf Fe (Fig. 8), Zn, and Cu (Table 7) by 60, 44, and 66%, respectively, compared to treatment without biochar with 60% water requirement, with the lowest rate being associated

Table 7 - Mean comparison interaction of biochar and drought stress on some characteristics of melon leaf

Treatment	Zn (ppm)	Cu (ppm)	Mn (ppm)
I1B1	44.07 bcd	9.51 d	44 d
I1B2	46.87 bcd	10.18 d	47.17 d
I1B3	54.97 ab	14.38 ab	51.51 bcd
I1B4	63. 7 a	15.75 a	51.98 bcd
I2B1	38.83 cde	9.98 d	49.68 cd
I2B2	35.2 de	10.55 d	50.9 bcd
I2B3	51.3 abc	11.92 bcd	56.88 abc
I2B4	45.5 bcd	13.98 ab	59.1 ab
I3B1	25.27 e	8.41 d	50.9 bcd
I3B2	42.37 bcd	11.35 bcd	52.73 bcd
I3B3	40.03 bcd	11.01 bcd	59.37 ab
I3B4	43.53 bcd	10.85 cd	65.34 a

In each column, mean values with the same letters do not have a significant difference in 1% probability level of the Duncan's test.

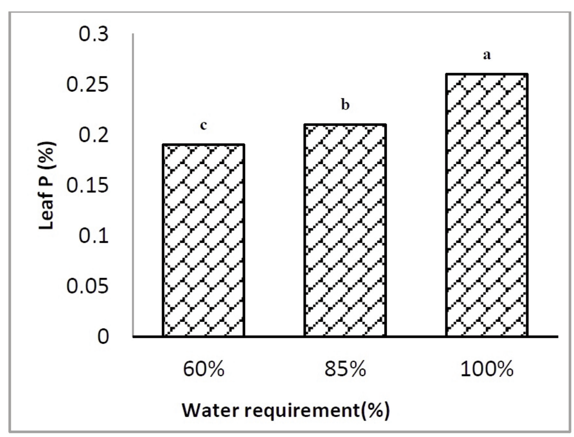

Fig. 6 - Effects of drought stress on melon leaf P.

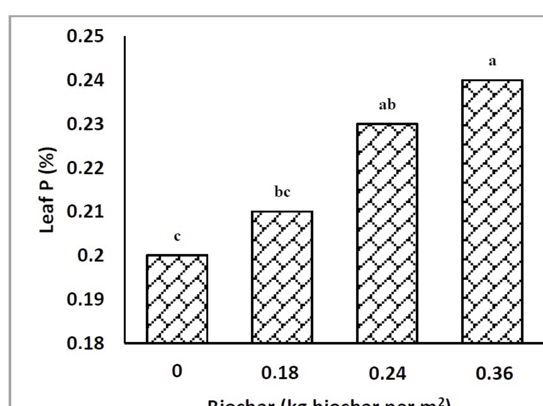

Fig. 7 - Effects of biochar on melon leaf P.

with the biochar-free treatment with 100% water requirement. For Fe, the treatments of I1B2, I1B3 and I1B3 had not significantly difference to each other and with compared to I2B3 and I2B4 (Fig. 8). The leaf Zn content of the treatments of I1B3 and I1B4 and I2B3 was not significantly different (Table 7). In the case of Cu, the treatments of I1B3 and I1B4 were not significantly different from I2B4 (Table 7). The lowest level of proline was related to I3B3, and it was not significantly different from the treatment of I3B4. Moreover, the highest rate of proline was related to the biochar-free treatment and 60% drought stress and was significantly different from other treatments (Fig. 9).

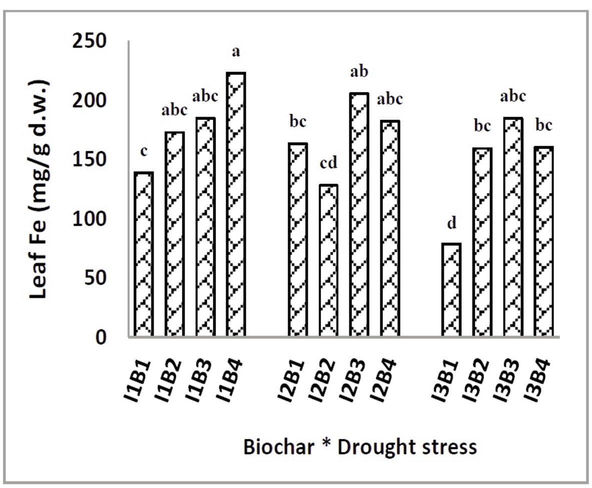

Fig. 8 - Effects of the interaction of biochar and drought stress on melon leaf Fe.

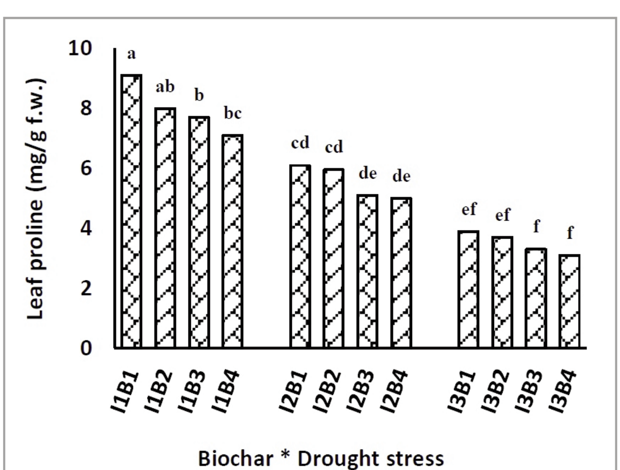

Fig. 9 - Effects of the interaction of biochar and drought stress on leaf proline content of melon plants.

4. Discussion and Conclusions

Reduction in water resources affects the physiological processes of the plant and hence reducing the growth and yield. In this experiment, the water shortage of root media was compensated with the application of biochar and hence increasing in water holding capacity, and the water use efficiency of plant improved without decreasing growth and by increasing the nutrient supply and hence total yield. The treatments of I3B3 and I3B4 increased water use efficiency by 88 and 76% compared to the treatment of I1B1 respectively, but there was no significant difference compared to the treatments of I3B2, I2B3 and I2B4. In this experiment, no significant difference was observed between 85% and 100% water requirement, particularly in 0.24 and 0.36 Kg/m^2, indicating the fact that biochar application in 85% water requirement significantly reduced plant water use and hence, a significant effect on the water use efficiency of the plant. Akhtar *et al.* (2014) reported that the use of biochar obtained from rice bran and flaxseed increased water use efficiency in all irrigation treatments compared to the biochar-free conditions. Uzoma *et al.* (2011) indicated that the application of 10, 15, and 20 tons cow manure biochar per hectare significantly increased the water use efficiency of corn plants in a sandy soil. I3B3 treatment increased the shoot fresh weight, shoot dry weight, root fresh weight, root dry weight and root length by 77, 32, 100, 84, and 71%, respectively compared to the treatment of I1B1. The treatment of I3B3 had no significant difference in comparison to the treatments of I3B4 and I2B3.

Roots grew well in biochar beds, which can be due to the improvement of the physical and chemical conditions of the soil and therefore, reducce the soil resistance to the root growth (Chan *et al*., 2008). Biochar can improve water permeability of the soil and facilitate root infiltration and increase root weight and length.

The highest shoot length, leaf area, and leaf number per plant were related to I3B4 in compared to I1B1 treatment, however treatment of I3B4 was not significantly different from the treatment of I3B3. In this experiment, decrease in irrigation and increase in plant stress caused decrease in the shoot length, leaf area, and leaf number per plant, and with increased irrigation and biochar application, and hence decreasing stress, these values increased. In the stress conditions, the plant size reduces due to reduced transpiration, hence reducing its leaf cells and leaf size. With increasing water use efficiency and thus decreasing stress, the biochar leads to an increase in the leaf area and leaf number per plant (Olympios, 1992). The shoot length increases because of the effect of biochar in increasing available P that causes increase in root growth and absorption of nutrients (Hossain *et al*., 2010). Moreover, Sang and Gio (2012) showed that the biochar with increasing chlorophyll content, leads to the improvement of photosynthesis, carbohydrate synthesis and biomass production; the result of which include the increase in the leaf area, leaf number per plant, hence increase in weight and length of the root and shoot of the plant. The treatment of I3B4 increased fruit diameter and fruit flesh diameter by the rate of 43 and 55 in compared to the treatment I1B1, although there was no significant difference between the treatments of I3B3. In this experiment, fruit diameter, fruit flesh diameter and hence the yield increased with the application of biochar. This is due to the nutritional elements available in the palm leaves (direct) and also the improvement of soil physical, chemical and biological characteristics (indirect) by biochar (Major *et al*., 2010). Biochar significantly leads to increase in the organic carbon and soil fertility (Kumar *et al*., 2013), increased growth and crop yield (Spokas *et al*., 2010), and increased plant dry matter (Van Zwietn *et al*., 2007). The treatment of I3B3 increased the average fruit weight and plant yield by 84% compared to the I1B1 treatment, however it was not significantly different compared to the treatment of I3B4, I2B4, and I2B3. Other researchers (Zhang *et al*., 2010) also attributed the increase in corn growth and yield in biochar treatments to increased availability of the nutritional elements and improved physical properties of the soil, such as decreasing the apparent density. Furthermore, biochar improves soil chemical properties including functional groups and CEC (Kharea *et al*., 2013), in addition to increased plant access to nutrients and improved plant growth (Lehmann and Joseph, 2009). Uzoma *et al*. (2011) indicated that biochar application increased the growth and yield of corn compared to control, and had a significant effect on shoot length and number of leaves in different stages of corn growth in sandy soil. In this experiment, addition of 0.19, 0.24, and 0.36 Kg/m^2, especially the treatments of 0.24 and 0.36 Kg/m^{2}and without stress, increased other vegetative characteristics. Moreover, the application of biochar with 85% water requirement did not significantly change these characteristics, but increased stress (60% water requirement) decreased plant vegetative properties. N is considered as a mobile element, so N level reduces in conditions of water shortage. Accordingly, it can be conclusively claimed that the addition of biochar to the soil, by increasing water retention, decreases the nitrate leaching from the soil and increases the availability of N in the soil, and this effect is stable for at least five months (Clough *et al*., 2013). Generally, there are varying reports on the effect of drought stress on nutrient content in plant species. The decreased rate of N in water shortage conditions (Muni Ram and Singh, 1995; Alam, 1999) and its strengthening under drought stress have been reported (Abdel Rahman *et al.*, 1971). In this experiment, the treatments of I1B4, I1B3 and I1B2 increased N content of the plant as 34, 32 and 10%, the treatments of I2B4, I2B3 and I2B2 increased N content of the plant as 52, 54, and 28%, and finally the treatments of I3B4, I3B3 and I3B2 increased N content of the plant by 58, 50 and 41% compared to treatment I1B1. It is concluded that the plant N content increases with application and increasing the biochar level and decreasing drought stress.

Results showed that biochar utilization increased leaf P content under stress and non-stress conditions. The effects of organic matter on increasing P availability in the soils depend on their phosphorus content. Due to the low amount of absorbable phosphorus in palm leaf biochar, this increase can be attributed to acids released from organic matter. These acids reduce the P stabilization in the soil and transform it into an absorbable form. The absorption of nutrients and available water by plant roots are closely related to each other. Water relations affect all physiological processes related to the solubility and availability of nutrients (Alam, 1999). In this experiment, application of 0.36, 0.24, and 0.19 Kg/m^2 increased 20, 15, and 5% of plant P, respectively, in comparison to the control (without biochar). Moreover, the treatments of 100% and 85% of water requirement increased the plant's P rate as respectively 36% and 10% in comparison to the treatment of 60% of water requirement. It can be concluded that the leaf P content increased with increasing biochar level and decreasing drought stress. Biochar application increased K under stress and non-stress conditions. Increasing the soluble K due to the application of biochar depends on their composition, especially their K content, the rate of K release, and the effect of organic molecules on the release of K from soil minerals (Jalali, 2011; Najafi-Ghiri, 2015). At the presence of higher water rate, univalent ions such as K in the soil solution increase relatively more than bivalent ions such as Ca and Mg, however as the soil becomes dry gradually, clay colloids absorb K (univalent ions) more strongly to their surface and prevent the separation of these ions (Kafi *et al*., 2009). In addition, since the overall growth of the plant, including the absorption activity of roots reduces due to stress, they will not be able to absorb K from the surface of clay colloids and, hence, the rate of absorption of these elements decreases (Radin and Eidenbock, 1984). In the present experiment, treatments of I1B4, I1B3 and I1B2 increased the K rate as 13, 18, and 9%, also, treatments of I2B4, I2B3 and I2B2 increased the K rate as 39, 27, and 23%, and finally treatments of I3B4, I3B3 and I3B2 increased the K content by 65, 47, and 30%, respectively. This results leads to the conclusion that the addition of biochar reduces stress and, as a result, increases the K content of the plant. Biochar application increased Fe, Zn, and Cu under stress and Mn under non-stress conditions. The researchers have suggested that drought stress stops the activity of older roots and only the tip of the roots absorb nutrients, hence the bivalent cations such as iron are absorbed more than the univalent ones and adsorption of the anions is limited (Martins *et al*., 2003). In the case of Zn and Cu elements, maybe in conditions of drought stress, continuous wetting and drying in the soil leads to the release of these elements from the clay layers and their concentration increases in the soil, hence increasing the adsorption phenomenon (Logan *et al.*, 1997). Mn and Fe have an inverse relationship with each other in terms of absorption by the plant, that is, increasing the Mn absorption decreases the Fe absorption (Martins *et al*., 2003). Changes in the availability of micro elements in the soil are affected by the characteristics of organic matter and soil. The nutrients of organic matters are released through its decomposition. Although various mechanisms are responsible for increase or decrease of retaining nutrients in the soil (Sposito, 1984), studies have shown that adding biochar to the soil is effective on the capability of use of ions due to affecting ion exchangable capacity and microbial activity (Atkinson *et al*., 2010). In an experiment, drought stress increased soil Zn and Cu and reduced Mn (Alizadeh *et al*., 2008). Drought stress increased Zn, Fe, and Cu content in the sage plant (Sodaeizadeh and Mansouri, 2014). In an experiment, biochar application increased Fe and Mn elements in amaranth plant (Habibi *et al*., 2017). In this experiment, 60 and 85% water requirement increased the Fe content (76 and 107%), Zn (74 and 13%), and Cu (13 and 18%) compared to the 100% water requirement (without stress) and the treatments of 0.24 Kg/m^2 in 60 and 85% water requirement and 0.36 Kg/m^{2}in 60 and 85% stress, increased the Fe rate as 33%, 48%, 60%, and 32%, the Zn as 24, 16, 44, and 3%, and Cu as 51, 25, 65, and 47% respectively, compared to the treatment of I1B1. Moreover, in the present experiment, the Mn level increased with the use of biochar and decrease in the drought stress, so that treatments of I1B4, I1B3 and I1B2 increased the Mn by 18, 17, and 7%, the treatments of I2B4, I2B3 and I2B2 increased the Mn by 34, 29, and 15%, and eventually, the treatments of I3B4, I3B3 and I3B2 increased the Mn by 38, 44, and 19%, respectively.

The use of biochar reduced proline content under stress and non-stress conditions. This finding suggests that biochar decrease the water evaporation and keeping moisture in the root media, because of its large pores on its surface or improving the soil texture, and can improve root growth and hence reduce stress. Under drought stress conditions, the water potential of the leaf decreases substantially, which, solutions such as proline accumulation in the leaf in order to adapt to the osmotic conditions. Proline decreases in leaves under stress due to decreased synthesis and increased oxidation. It was observed that drought stress caused reduction in leaf water capacity of grape and, thus, increased proline and proline rate was reduced through the use of biochar in cultural media (Rasouli and Golmohammadi, 2009). In this experiment, the proline content decreased with increasing biochar treatments from 0.19 to 0.36 Kg/m^2 and the increase of water requirement from 60 to 100%, with the lowest amount of proline being related to 0.24 and 0.36 Kg/m^{2}and 100% water requirement.

The results of this study revealed that adding palm leaf biochar to the soil especially in drought stress conditions reduces the water consumption rate and improve plant growth and yield. Treatments of 0.24 Kg/m^{2}and 100% water requirement increased the shoot fresh weight, root fresh weight and plant yield compared to without biochar and 60% water requirement. In general, the most effective treatments were 0.24 and 0.36 Kg/m^2 and there was no significant difference between these treatments in most of the characteristics. Using biochar, especially 0.24 and 0.36 Kg/m^2, could compensate the drought stress effects and improve plant growth and yield.

References

ABDEL RAHMAN A.A., SHALABY A.F., MONAYERI M.O.E.I., 1971 - *Effect of moisture stress on metabolic products and ions accumulation.* - Plant Soil, 34: 65-90.

AKHTAR S.S., ANDERSEN M.N., LIU F., 2014 - *Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress*. - Agric. Water Manag., 158: 61-68.

ALIZADEH A,. MAJIDI A., MOHAMMADI GH., 2008 - *Effect of water stress and soil nitrogen on nutrients absorption in corn plant ksc 704.* - J. Res. Agric. Sci., 4(1): 51-59.

ALAM S.M., 1999 - *Nutrient uptake by plants under stress condition*. pp. 285-315 - In: M. PESSARAKLI (ed.) *Handbook of plant and crop stress*. 2nd edition. - Marcel Dekker Inc., New York, NY, USA, pp. 1254.

ASGHARI SH., 2011 - *Effects of Tabriz petrochemical sewage sludge on organic carbon, aggregate stability indices and consistency limits of a semiarid soil*. - J. Water Soil, 25(3): 530-539.

ASHRAF M., FOOLAD M.R., 2007 - *Roles of glycine betaine and proline in improving plant abiotic stress resistance*. - Environ. Exp. Bot., 59: 206-216.

ATKINSON C.J., FITZGERALD J.D., HIPPS N.A., 2010 - *Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: A review*. - Plant Soil, 337: 1-18.

BASSO A.S., MIGUEZ F.E., LAIRD D.A., HORTON R., WESTGATE M., 2013 - *Assessing potential of biochar for increasing water-holding capacity of sandy soils.* - G.C. B. Bioenergy, 5: 132-143.

BATES L.S., WALDREN R.P., TEARE I.D., 1973 - *Rapid determination of free proline for water-stress studies*. - Plant Soil, 39(1): 205-207.

BREMNER J.M., 1996 - *Nitrogen total*, pp. 1085-1121. - In: SPARKS D.L. (ed.) *Methods of soil analysis. Part 3. Chemical methods*. Soil Sci. Soc. of America, Madison, WI, USA, pp. 1390.

CARTER S., SHACKLEY S., SOHI S., SUY T., HAEFELE S., 2013 - *The impact of biochar application on soil properties and plant growth of pot grown lettuce (*Lactuca sativa*) and cabbage (*Brassica chinensis*)*. - Agronomy, 3(2): 404-418.

CHAN K.Y., ZWIETEN L.V., MESZAROS I., DOWNIE A., JOSEPH S., 2008 - *Using poultry litter biochars as soil amendments*. - Australian J. Soil. Res., 46: 437-444.

CLOUGH T.J., CONDRON L.M., KAMMANN C., MÜLLER C., 2013 - *A review of biochar and soil nitrogen dynamics*. - Agronomy, 3: 275-293.

GLASER B., BIRK J.J., 2012 - *State of the scientific knowledge on properties and genesis of Anthropogenic Dark Earths in Central Amazonia (terra preta de Índio)*. - Geochim. Cosmochim. Acta, 82: 39-51.

HABIBI H., MOTASHAREH ZADEH B., ALIKHANI H., 2017 - *Effect of biochar and biological treatments on nutrient elements content (P, K, Ca, Mg, Fe and Mn) of* Amaranthus *in oil polluted soil.* - Iran. J. Soil. Water. Res., 48(2): 369-384.

HALL G., WOODBORNE S. SCHOLES M., 2008 - *Stable carbon isotope ratios from archaeological charcoal as palaeoenvironmental indicators*. - Chem. Geol., 247(3-4): 384-400.

HELMKE P.A., SPARKS D.L., 1996 - *Lithium, sodium, potassium, rubidium and cesium*, pp. 551-574. - In: SPARKS D.L. (ed.) *Methods of soil analysis. Part 3. Chemical methods*. Soil Sci. Soc. of America, Madison, WI, USA, pp. 1390.

HEMMAT A., AGHILINATEGH N., SADEGHI M., 2010 - *Shear strength of repacked remoulded samples of a calcareous soil as affected by long-term incorporation of three organic manures in central Iran*. - Biosyst. Eng., 107(3): 251-261.

HOSSAIN M.K., STREZOV V., YIN CHAN K., NELSON P.F., 2010 - *Agronomic properties of wastewater sludge biochar and bioavailability of metals in production of cherry tomato (*Lycopersicon esculentum *L.)*. - Chemosphere, 78(9): 1167-1171.

JACKSON, M.L., 2005 - *Soil chemical analysis: Advanced course*. - UW-Madison Libraries, Parallel Press, Madison, WI, USA, pp. 930.

JALALI M., 2011 - *Kinetics of non-exchangeable potassium release and availability in some calcareous soils of western Iran*. - Geoderma, 135: 63-71.

KAFI M., BORZUEI A., SALEHI M., KAMANDI A., MASOMI A., NABATI J., 2009 - *Plant stress physiology*. - Mashhad Jahad Daneshgahi Publication, pp. 502.

KHAREA P., DILSHADA U., ROUTB P.K., YADAVA V., JAINA S., 2013 - *Plant refuses driven biochar: Application as metal adsorbent from acidic solutions*. - Arab. J. Chem., 10(S2): S3054-S3063.

KUMAR S., MASTO R.E., RAM L.C., SARKAR P., GEORGE J., SELVI V.A., 2013 - *Biochar preparation 373 from* Parthenium hysterophorus *and its potential use in soil application*. - Ecol. Eng., 55: 67-72.

LEHMANN J., JOSEPH S., 2009 - *Biochar for environmental management: Science and technology*. - Earthscan, London and Sterling, VA, USA., pp 404.

LIU E.K., MEI X.R., YAN C.R., GONG D.Z., ZHANG Y. Q., 2015 - *Effects of water stress on photosynthetic characteristics, dry matter translocation and WUE in two winter wheat genotypes*. - Agric. Water Manag., 167: 75-85.

LOGAN T.J., GOINS L.E., LINDSAY B. J., 1997 - *Field assessment of trace element uptake by six vegetables from N-viro soil*. - Water. Environ. Res., 69: 28-33.

MAJOR J.M., RONDON D., MOLINA S., RIHA J., LEHMANN J., 2010 - *Maize yield and nutrition during 4 years after biochar application to a colombian savanna oxisol.* - Plant Soil, 333: 117-128.

MARTINS A.L.C., BATAGHA O.C., CAMARGO O.A., CONTARELLA H., 2003 - *Corn yield and uptake of Cu, Fe, Mn and Zn from sewage sludge-amend soil with and without liming*. - Rev. Bras. Cienc. Solo, 27: 563-574.

MESA A.C., SPOKAS K.A., 2011 - *Impacts of biochar (black* *carbon) additions on the sorption and efficacy of herbicides*, pp. 317-340. - In: KORTEKAMP A. (ed.) *Herbicides and environment*. IntechOpen, London, UK, pp. 746.

MUNI RAM R.D., SINGH S., 1995 - *Irrigation and nitrogen requirements of Bergamot mint on a sandy loam soil under sub-tropical conditions*. - Agric. Water Manag., 27(1): 45-54.

NAJAFI-GHIRI M., 2015 - *Effect of different biochars application on some soil properties and potassium pools distribution in a calcareous soil*. - J. Soil Sci., 29: 351-358.

NAZMI L., SHABANPOUR M., HASHEMI K., 2012 - *Effect of type and amount of organic wastes on properties of two types of soil*. - J. Soil Water Conserv., 25: 93-102.

NIGUSSIE A., ENDALKACHEW K., MASTAWESHA M., GEBERMEDIHIN A., 2012 - *Effect of biochar application on soil properties and nutrient uptake of Lettuces* (Lactuca sativa) *grown in chromium polluted soils*. - American-Eurasian J. Agri. Environ. Sci., 12: 369-376.

OLYMPIOS C., 1992 - *Soilless media under protected cultivation rockwool, peat, perlite and other substrates*. - Acta Horticulturae, 323: 215-234.

RADIN J.W., EIDENBOCK M.P., 1984 - *Hydraulic conductance as a factor limiting leaf expansion of phosphorus-deficient cotton plants*. - Plant Physiol., 75: 372-377.

RASOULI V., GOLMOHAMMADI M., 2009 - *Evaluation of drought stress tolerance in grapevine cultivars of Qazvin province*. - Seed Plant Improv. J., 2: 349-359.

SANGEETHA M., SINGARAM P., UMA DEVI R., 2006 - *Effect of lignite humic acid and fertilizer on yield of onion and nutrient availability*. - Inter. Union Soil Sci., 18th World Congress of Soil Science, Philadelphia, PA, USA, 21: 163-168.

SINAKI J.M., HERAVAN E.M., SHIRANI A.H., NOORMOHAMMADI G., ZAREI G., 2007 - *The effects of water deficit during growth stages of canola (*Brassica napus *L.).* - J. Agri. Environ. Sci., 2(4): 417-422.

SODAEIZADEH H., MANSOORI F., 2014 - *Effects of drought stress on dry matter accumulation, nutrient concentration and soluble carbohydrate of* Salvia macrosiphon *as a medicinal plant*. - Arid Biome., 4(1): 1-9.

SPOKAS K.A., BAKER J.M., REICOSKY D.C., 2010 - *Ethylene: potential key for biochar 420 amendment impacts*. - Plant Soil, 333: 443-452.

SPOSITO G., 1984 - *The surface chemistry of soils*. - Oxford Univ. Press, New York, USA., pp 234.

SUN Z., BRUUN E.W., ARTHUR E., DE JONGE L.W., MOLDRUP P., HAUGGAARD-NIELSEN H., ELSGAARD L., 2014 - *Effect of biochar on aerobic processes, enzyme activity, and crop yields in two sandy loam soils*. - Biol. Fert. Soil, 50: 1087-1097.

TATE R. L., 2000 - *Soil Microbiology*. - John Wiley and Sons. Inc., New York, USA., pp. 536.

UZOMA K., INOUE M., ANDRY H., FUJIMAKI H., ZAHOOR A., NISHIHARA E., 2011 - *Effect of cow manure biochar on maize productivity under sandy soil condition*. - Soil Use Manage, 27: 205-212.

VAN ZWIETEN L., MORRIS S.S., CHAN K., DOWNIE A., RUST J., JOSEPH S., COWIE A., 2010 - *Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility*. - Plant Soil, 327(1-2): 235-246.

YIN CHAN K., XU Z., 2009 - *Biochar: nutrient properties and their enhancement*. pp. 67-84. - In: LEHMANN J., and S. JOSEPH (eds.) *Biochar for environmental management: Science and technology*. Earthscan, London and Sterling, VA, USA., pp 404.

ZHANG A., CUI L., PAN G., LI L., HUSSAIN Q., ZHANG X., ZHENG J., CROWLEY D., 2010 - *Effect of biochar amendment on yield and methane and nitrous oxide emissions from a rice paddy from Tai Lake plain, China*. - Agri. Ecosys. Environ., 139: 469-475.