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Impact of biochar, compost and biochar-compost mixture on chlorophyll and morphological characteristics of bell pepper

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Abstract
Sandy soils have properties of low organic matter, productivity, high infiltration, and hydraulic conductivity and evaporation rates under arid land conditions. Soil management such as amendment materials such like biochar, compost and biochar-compost mixture were applied at two rate (2 and 4% by weight) for improving hydro-physical properties of sandy soil under technique of partial root zone drying irrigation system (PRD) with two level of irrigation water; $PRD_{50\%ETC}$, 50% ETc and $PRD_{75\%ETC}$, 75% ETc under greenhouse environment. The treatments of amendment materials were B2 (2%biochar), CO2 (2% compost), B4 (4%biochar), CO4 (4% compost), Mix2 (1%biochar+1%compost and Mix4 (2%biochar+2%compost). The main objectives of this study were: (***a***) to determine the impacts of PRD and biochar, compost and their mixture on chlorophyll content of bell pepper. (***b***) to assess the effects of biochar and compost on morphological properties of bell pepper under PRD irrigation techniques. The data obtained from this study shows that the morphological characteristics and chlorophyll of bell pepper were affected by amendment materials and PRD technique. The main concluded point from this study was the possibility of using the mixture of biochar and compost and PRD for improving yield, water saving and WUE of bell pepper under sandy greenhouse conditions.

Keywords: biochar, biochar-compost mixture, chlorophyll, morphological characteristics, bell pepper, partial root zone drying irrigation

Introduction

Partial root zone drying irrigation strategies (PRD) is a modified type of deficit irrigation where half of the root system is subject to irrigation and the other half is growing under drying soil in each irrigation event. Deficit irrigation (DI) of pepper may be difficult to manage since decreases in crop yield, quality, and quantity can derived from even brief periods of water stress during crop development stages (Katterji *et al*., 1993; Jaimez *et al*., 2000; Della Costa and Gianquinto, 2002; Fernandez *et al*., 2005) [31, 29, 19, 21]. Akhtar *et al*. (2014) [11] reported on study under greenhouse conditions using full irrigation (FI), DI and PRD for tomato that a significant increase in water use efficiency (WUE) by 35% and 15% for PRD and DI compared to FI, similar finding was reported by (Shao *et al*. 2008,; Alrajhi *et al*, 2017) [50, 14].

Recently, organic soil amendments (important sources of carbon and nitrogen) such as farm crop residues, biochar, compost, and biochar-compost mixture were applied to the sandy soil with purpose of improving the physical properties and producing good productive soil structure (Abubakari *et al*., 2016; Abujabhah *et al*., 2016; Agegnehu *et al*., 2016; Hussain *et al*., 2016; Seehausen *et al*., 2017; Hien *et al*., 2017) [3, 4, 7, 25, 48, 24]. Arid areas with low rainfall or nutrient-poor soils such as sandy soil will most likely appreciate the largest impact from adding biochar (Gebremedhin *et al*., 2015) [22]. Due to negatively charged surfaces and high surface area, biochar amendments enhanced water holding capacity, water retention and irrigation requirements, accordingly protected the crops against water deficiency (Hafeez *et al*., 2017) [23]. On the other hand, compost is a key ingredient in vegetable farming. It is a single vital supplement to the soil, simple way to add nutrient-rich humus, which helps plant growth and restores vitality to depleted soil. Concerning rising cost of mineral fertilization and even deteriorating prospects with respect to the limited stock of nitrogen, phosphorus and other elemental supplements, a beneficial combination of biochar and compost has been approved (Schulz and Glaser, 2012; Prost *et al*., 2013; Schulz *et al*., 2013) [45, 42].

Pepper (*Capsicum annuum* L.) is considered as sensitive to very sensitive to water stress (Dagdelen *et al*., 2004; Shao *et al*., 2010; Lodhi *et al*., 2014) [16, 50, 35], whether provoked by deficit of water. The influence of water stress on pepper growth and yield is controversial. Although adverse effects of water stress on growth and yield of pepper have been reported by many investigators as Antony and Singandhupe (2004) [15]; Dagdelen *et al*. (2004) [16]; Sezen *et al*. (2006) [49]; Ismail (2010; 2012) [6]; Abayomi *et al*. (2012) [1]; AlHarbi *et al*. (2014) [13] and Ahmed *et al*. (2014) [10], others found no effects resulted from water stress (Ruiz-Lau *et al*., 2011) [43].

There has been an increasing interest in integrated organic amendment approaches for improving soil fertility, increasing WUE and crop productivity (Akhtar *et al*., 2015) [12]. Combination of biochar and compost has been studied in peanut and maize (Agegnehu *et al*., 2015a and b, and 2016) [8].

However, the effects of biochar application in integrated with compost are not fully understood (Trupiano *et al*., 2017) [54]. Moreover, the response of biochar and compost together has not been studied well in vegetables, particularly in sandy soils (Naeem *et al*., 2018) [39]. Keeping above in view, the current study has been established with the objectives: (*a*) to determine the impacts of PRD and biochar, compost and their mixture on chlorophyll content of bell pepper. (*b*) to assess the effects of biochar and compost on morphological properties of bell pepper under PRD irrigation techniques.

Materials and Methods

1. Soil management

Biochar production

The biochar, a carbon-rich, used in this experiment was prepared from the date palm. Date palm was selected based on its widespread availability in the Riyadh city. Using date palm as biochar raw material acts as a good solution that helps to solve those environmental problems from burning its leaves. Biochar was produced as following; date palm fronds were collected and exposed to the direct sunlight to dry out, and then cut down the petiole bases (fronds) to small pieces (20–30 cm). The pieces were packed in the biochar kiln. The kiln was subjected to outdoor pyrolysis at a high temperature of 400-450°C ± 10°C (Figure 1). The biochar pieces were crushed, manually, and for making them as small pieces and very small pieces, biochar were grinded by electrical grinder. After that, biochar materials were screened through a 2 mm sieve before mixing with the soil.

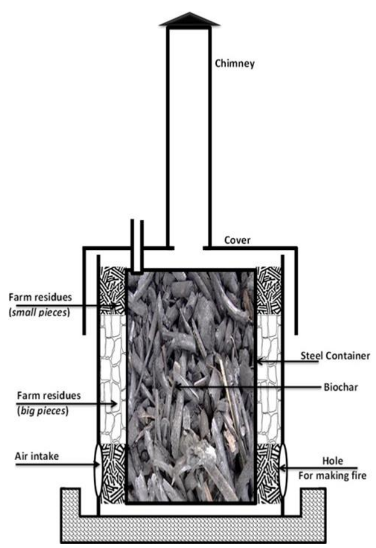


Fig 1: Schematic diagram of biochar kiln for slow pyrolyzed biochar (After Ibrahim, 2018)

Compost

Commercial compost was purchased from a local agricultural market in Riyadh city. The compost product was also screened through a 2 mm sieve before mixing with the soil.

Then, biochar and compost pH and electrical conductivity (EC) were measured using pH meter and a conductivity meter with 1:10 (w/v) suspension of biochar and compost on deionized water. Bulk density of soil biochar and compost was calculated by the dry weight of soil and compact weight of biochar and compost in a 100 cm^3 steel cylinder. The concentrations of elemental C, H, N, P and K were examined using an elemental analyzer. Biochar and compost total N, P, K was determined after wet digestion with salicylic-sulfuric acids and sodium thiosulphate. Then, total N analysis and total P were measured by Gilford 300N spectrophotometer at wavelength 625 nm and 710 nm, respectively; Total K was identified by using Polarized atomic absorption spectrophotometer. Hence, chemical and physical analyses of soil, biochar and compost used were presented in Table (1).

Table 1: Physico-chemical characteristics of compost and biochar

Parameter	Unit	Biochar	Compost
Specific surface area	$m^2 g^{-1}$	237.8	1.01
pH (H_2O)	-	8.92	7.84
EC (1:10)	$dS\ m^{-1}$	7.78	7.43
OM	%	30.32	40.71
C	%	60.00	26.15
H	%	3.44	4.21
N	%	0.24	1.30
P	%	0.22	1.00
K	%	0.87	1.20
Ca	%	5.63	0.92
C/N ratio	-	250:1	20:1
Moisture	%	3.53	3.64
Mobile material	%	22.82	17.19
Ash	%	25.70	71.23
Resident material (*Fixed carbon*)	%	47.95	7.94

2. Plant material and experimental conditions

To establish the partial root zone drying irrigation technique (PRD), and biochar (B) produced from date palm fronds waste biomass and commercial compost (CO) as organic amendments in enhancing sandy soil health for improving the growth, yield and water use efficiency (WUE) of bell pepper (*Capsicum annuum* L. var. Sonar), this study was conducted. A greenhouse experiment was achieved at the College of Agriculture Experimental Station, south Riyadh, Saudi Arabia, located at the coordinates 24° 39 N, 46° 44 E, from Sep. 2016 to Apr. 2017.

Bell pepper seeds were sown in 84 cell foam trays filled with peat moss: vermiculite (1:1 v/v) media at 19 Sep. 2016. Afterwards, trays were raised at the nursery greenhouse and cared by regular practices for seedlings production in nursery greenhouse. Five-week-old seedlings were transplanted into the production greenhouse at 25 Oct., 2016. Seedlings were planted on line 7 m long with emitters spaced at 0.5 m and distance between rows of 1.0 m. Temperature and relative humidity (RH) inside the greenhouse were kept at 26/19 ± 1°C day and night temperatures, and 75 ± 2% RH.

3. Partial root zone drying irrigation technique (PRD)

Surface drip irrigation designed inside the greenhouse using PRD technique, with plastic sheet between the two drip irrigation lines (Figure 1). The amount of irrigation for the 50 and 75% of ETc based on daily potential evapotranspiration and appropriate Kc values, as stated by Allen *et al*. (1998). A total quantity of irrigation water applied of 3500 and 5100 m^3

ha^{-1} for 50% and 75% ETc, respectively. Detailed layout and set-up of PRD were executed according to (Ibrahim, 2018).

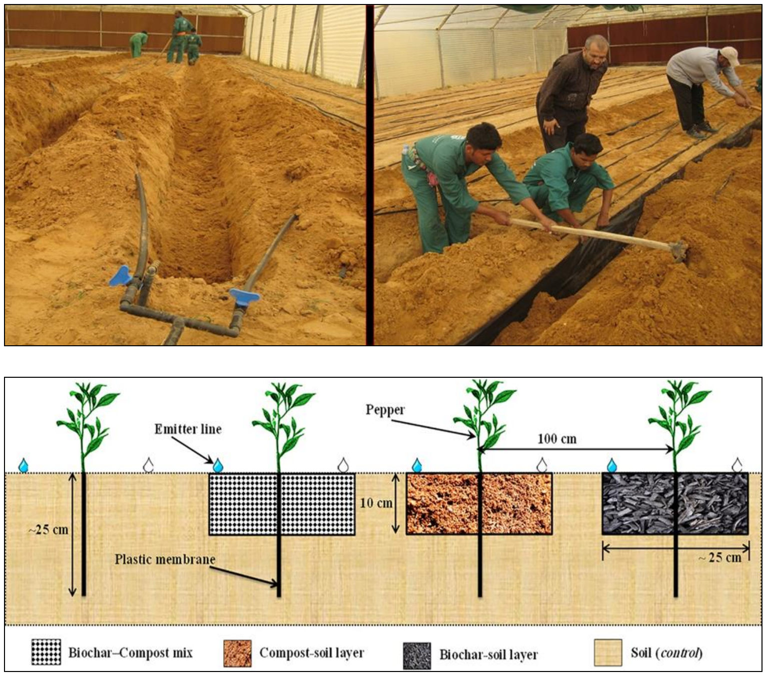


Fig 2: Set-up dual emitter lines as PRD technique, plant row and amended layer. (After Ibrahim, 2018)

Soil was collected from the greenhouse soil surface layer (0 to 15 cm depth). Sample of sandy soil was air dried and passed through a 2 mm stainless steel mesh sieve and then used for analysis. The selected soil properties were determined through standard procedure (Page *et al*., 1982) [54]. Tables 2, 3 and 4 show the properties of greenhouse soil and irrigation water. Properties were estimated according (Ibrahim, 2018).

Table 2: Some physio-chemical characteristics of soil properties (Ibrahim, 2018)

Sand, %	Silt, %	Clay, %	Texture	pH	EC dS m^{-1}	OM %	Bulk density kg m^{-3}
82.88	8.21	8.91	Loamy Sand	7.9	1.28	0.63	1400

Table 3: Soil soulble cations and anions, meq L-1 (Ibrahim, 2018)

Na^{+1}	K^{+1}	Ca^{+2}	Mg^{+2}	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}	$CaCO_3$, %
3.03	1.04	7.88	2.22	1.11	4.02	11.01	33.3

Table 4: Chemical characteristics of irrigation water (Ibrahim, 2018)

EC dS m^{-1}	pH	Cations (meq L^{-1})				Anions (meq L^{-1})			
		Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}
0.35	6.93	0.26	0.08	2.68	0.06	-	0.12	2.02	1.2

4. Experimental treatments

The experiment comprised nine treatments, representing combinations of two levels of irrigation water and seven soil amendments. The irrigation levels were $PRD_{75\%ETc}$ (75% ET_c) and $PRD_{50\%ETc}$ (50% ET_c). Seven soil organic amendments were; control (unamended soil), individual date palm biochar treatments (B4 and B2), and individual compost treatment (CO4 and CO2) of rate 4% and rate 2%, and two mixture treatment of biochar with compost (Mix4 and Mix2) at rates of (2% biochar + 2%compost) and (1% biochar + 1% compost).

Table 5: Experimental unit of amendment materials and irrigation (Ibrahim, 2018)

Treatments	No	Description
Irrigation level	2	- $PRD_{75\%ETc}$ (75% ET_c) - $PRD_{50\%ETc}$ (50% ET_c)
Treatments	7	- Control (Un-amended soil) - Biochar rate 4% (B4) - Biochar rate 2% (B2) - Compost rate 4% (CO4) - Compost rate 2% (CO2) - Biochar rate 2% + Compost rate 2% (Mix4) - Biochar rate 1% + Compost rate 1% (Mix2)

The experimental layout was a split-plot system in a randomized complete block design with three replications. Irrigation water rates were arranged as the main plots, and soil organic amendments (Control, B4, B2, CO4, CO2, Mix4 and Mix2) were randomly allocated to the sub-plots. The sub-plot area was 7 m^2, including 14 plants.

5. Experimental measurements

a. Chlorophyll content

Leaf chlorophyll content was estimated by a portable colorimeter apparatus (Minoline Camera SPAD-502 C. Japan), and expressed as SPAD units, in three plants per treatment (three true leaves $plant^{-1}$ under the top of plant), at flowering stage (60 days after transplanting).

b. Morphological characteristics:

At three periods during the growing season, three plants were randomly selected from each treatment in replication to measure three morphological characters per plant as follows:

1. Plant height (cm) was measured by a meter from the soil surface up to the top of plant.
2. The leaves number was carefully counted.
3. Stem diameter (cm) was measured by electronic calipers (near to the soil surface).
4. At the end of the experiment total plant leaf area (cm^2) was measured using a Portable Area Meter (LI-COR model 3000A).
5. The root system was carefully detached from the soil after washing off any trace of sand from the root surface to get a complete and clean root. Then, root depth (cm), and fresh and dry weights of root (g) were determined.
6. Dry matter production and partitioning:

Five bell pepper stands were harvested from each treatment at the end of the experiment (120 DAT) and separated into roots, stems, leaves and fruits. Fresh weight of each part was weighted with a digital balance. To determine dry weights of the individual plant part (100 g) sample from each organ was oven-dried at 75°C to a constant weight, and then weighted by the same digital balance.

Statistical Analysis

All data were analyzed using the statistical analysis system (SAS), version 9.0. Then, a revised least significant difference (LSD) test at $P \leq 0.05$ was used for searching significant differences among means following the procedure of Steel and Torrie (1980).

Results and Discussions

1. Chlorophyll content and leaf area

Reduction in chlorophyll content of pepper leaf tissues with the $PRD_{50\%ETC}$ treatment was significant compared with the control ($PRD_{75\%ETC}$), with percentage of reduction 7.07% (Figure 3). Low chlorophyll concentration may be associated with leaf senescence as a result of water deficit (Kirnak *et al*., 2002) [32]. Also, Ahmed *et al*. (2014) [10] found a significant decrease in chlorophyll content in a leaf of hot pepper by increasing irrigation water in deficit irrigation management. Smirnoff (1995) [51] reported that the decrease in chlorophyll content under water deficiency is mainly the result of chloroplasts damage that caused by active oxygen species. In parallel, the leaf area also significantly decreased in response to $PRD_{50\%ETC}$ treatment (Figure 3). The percentage of reduction was 9.29%, when compared with $PRD_{75\%ETC}$. The reduction in total leaf area probably attributed to the reduction in leaf number (Figure 5), leaf senescence and in rate of leaf emergence (Zewdie *et al*., 2007; A'fifah *et al*., 2013) [58, 5].

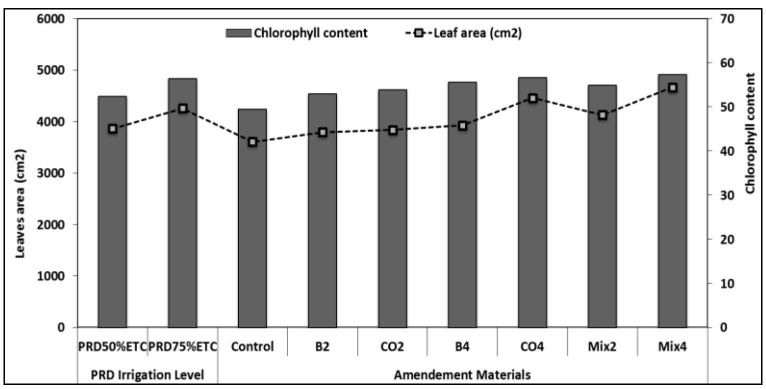


Fig 3: Effects of PRD water treatment and biochar, compost and their mixture leaf area and chlorophyll content of bell pepper plants

The highest values of chlorophyll content in leaf tissues were recorded with CO4 followed by Mix4 treatments. However, control treatment detected the lowest value (Figure 3). Leaf chlorophyll content, as an indicator of photosynthetic activity, is related to the N concentration in green plants and serves as a measure of crop response to soil N status (Minotta and Pinzauti, 1996) [37]. In our study, increased leaf chlorophyll content (Figure 3) was the indication of higher N concentration in bell pepper tissues with the previous treatments (i.e., CO4 and Mix4). Moreover, plants fed with Mix4, and CO4 showed superior influences on leaf area than other soil amendments (Figure 3). The higher increases in leaf area were observed with Mix4 (29.38%), followed by CO4 (23.63%), compared to those no feeding without any amendment (control treatment). That may be attributable to the improved nutrient supply by biochar with compost and associated nutrient input relative to that sole biochar treated soil or the control treatment (Naeem *et al*., 2018) [39].

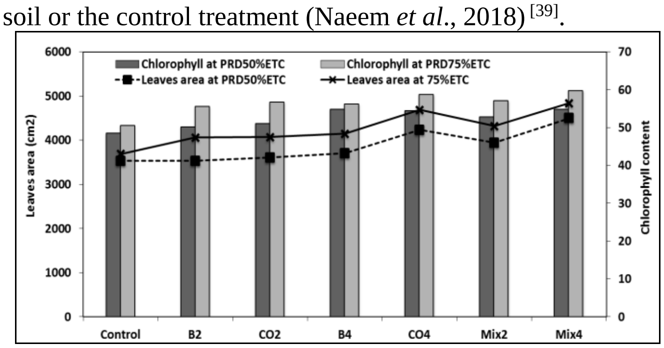


Fig 4: Combined effects of PRD water treatment and biochar, compost and their mixture on leaf area and chlorophyll content of bell pepper plants

There was a general increase in leaf area and chlorophyll content of bell pepper plants grown on soil amended with biochar, compost or their integrated under $PRD_{50\%ETC}$ or $PRD_{75\%ETC}$ compared specially to no amendment under PRD ($PRD_{50\%ETC}$) treatment which detected the least mean values. There were variations among organic soil amendment under two water amounts applied. For instance, Mix4 followed by CO4 under $PRD_{75\%ETC}$ recorded the highest mean values of leaf area and chlorophyll content traits (Figure 4). Chlorophyll content of leaf tissues is a practical indicator of both potential photosynthetic productivity and general plant vigor, which is related to the N concentration in green plants and serves as a measure of the response of crops to N fertilizer application and soil nutrient status (Agegnehu *et al*., 2015a) [9]. The positive impacts of biochar-compost mixture with $PRD_{75\%ETC}$ on bell pepper leaf area and chlorophyll content response were due to their influences on plant nutrition and water retention. Since, the optimum use of biochar and compost improves nutrient and water retention (Abubakari *et al*., 2016) [3].

2. Morphological characteristics

Though total amount of water applied to pepper plant through the entire growing period was important, the timing of the applied irrigation water was more critical (Kirnak *et al*., 2002) [32]. Data exhibited that the morphological characteristics of pepper plants were influenced by water treatments during the various growth stages (Figure 5).

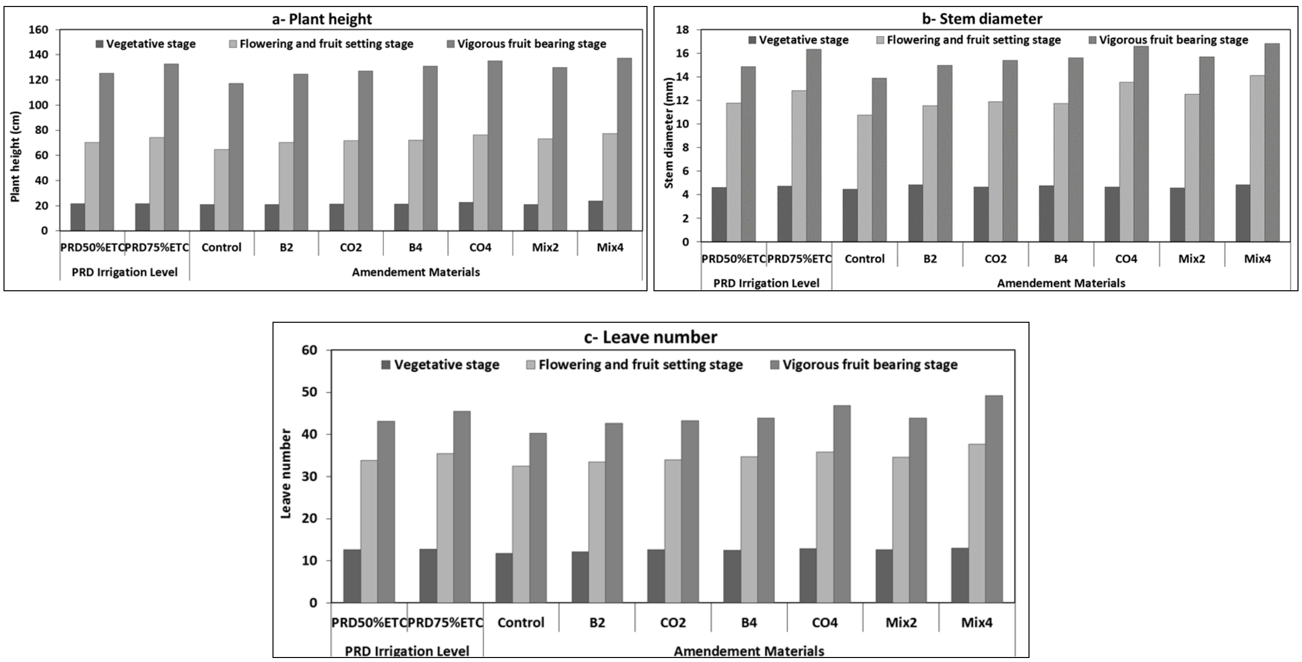


Fig 5: Effects of PRD water treatment and biochar, compost and their mixture on plant height, stem diameter and leave number of bell pepper plants

Reduction in the water supply ($PRD_{50\%ETC}$) caused significant decreases in the plant height, stem diameter and number of leaves during flowering and fruit setting, and vigorous fruit bearing stages. However, it did not affect the previous growth traits during earlier vegetative stage, when compared with $PRD_{75\%ETC}$. This finding indicated that vegetative growth stage is not sensitive to the water reduction. This finding supported our prior work (AlHarbi *et al*., 2014) [13] that DI from 75% to 50% ETc during vegetative growth period did not influence plant growth traits of pepper plants. The highest reduction in plant height, stem diameter and leaves number were 5.53%, 9.05% and 5.13%, respectively recorded in vigorous fruit bearing stag. Such reduction in these growth traits suggests that DI is one of the main factors which determine growth and development in bell pepper (A'fifah *et al*., 2013) [5]. In general, moisture in optimum level enhances the cell metabolism resulting in an increase in released energy which induces growth of bell pepper plants (Lodhi *et al*., 2014) [35].

Amending soil with Mix4 or CO4 increased significantly the plant height during three growth stages, and stem diameter, chiefly during flowering and fruit setting and vigorous fruit bearing stages. However, amending soil with Mix4 showed its significantly effect on leave number through the flowering and fruit setting and vigorous fruit bearing stages in comparison with all amendment treatments. On the contrary, lower significant values of three morphological characteristics during the different growth stages of plants were recorded with control treatment (Figure *5*). Organic amendments influence soil properties in various and variable ways. Effects can be direct, throughout the inherent properties of the organic amendments themselves, or indirect, by modifying soil physical, chemical and biological properties, which all leading to enhanced soil productivity and plant growth (Larney and Angers, 2012) [34]. On the contrary to water supply affect, amending the soil with Mix4 or CO4 increased significantly the plant height and leave number during the vegetative stage (Figure 5). Trupiano *et al*. (2017) [54] reported that the compost alone amendment showed the best clear and positive influences on lettuce plant growth.

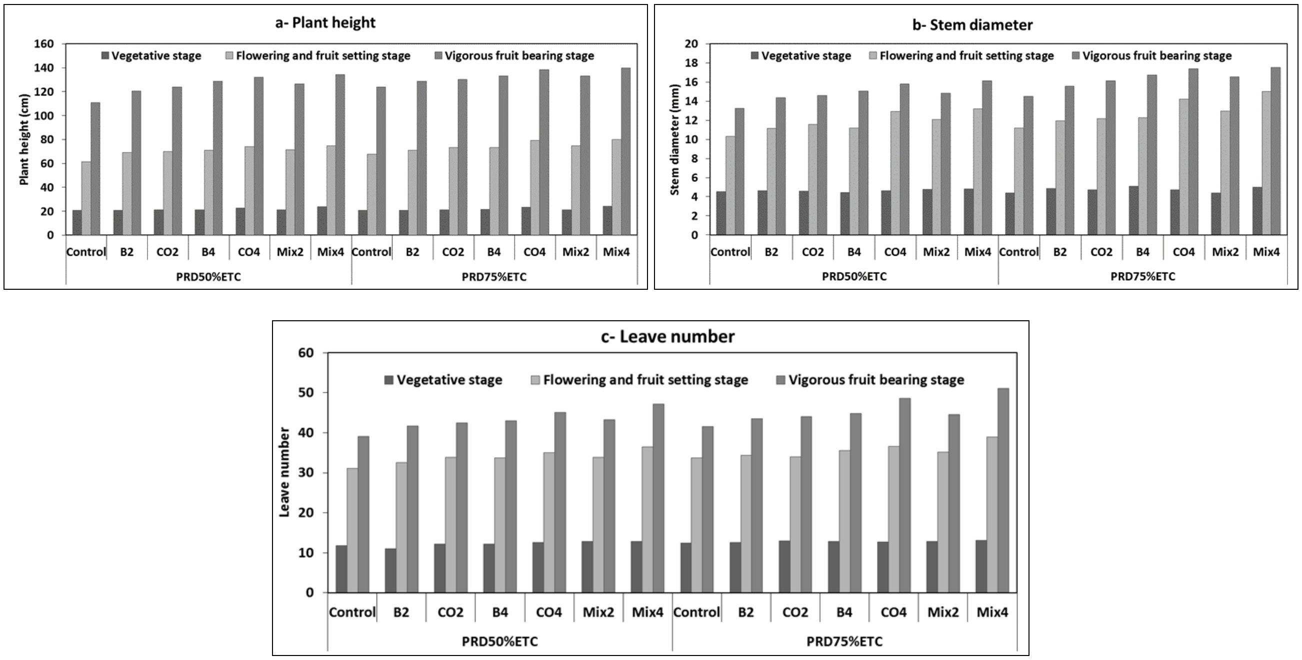
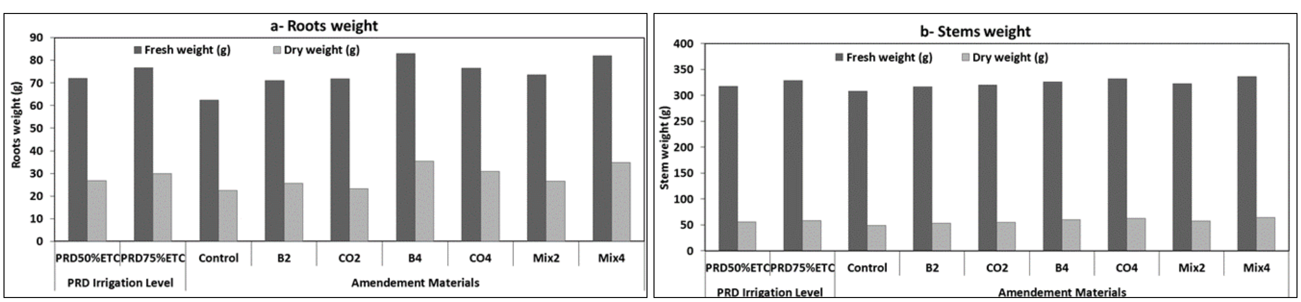


Fig 6: Combined effects of PRD water treatment and biochar, compost and their mixture on on plant height, stem diameter and leave number of bell pepper plants

The interaction between PRD treatments and organic soil amendments did not show clear effect on morphological characteristics (plant height, stem diameter and number of leaves), particularly during vegetative period except for plant height, where Mix4 followed by CO4 with both PRD treatments reflected significant effect than other treatments (Figure 6). The observed increase in the mean plant height (Figure 5) in response to Mix4, and CO4 treatments is might be consistent with improved soil chemical fertility. These findings are in accordance with those of Ellen *et al.* (2010) [20] who reported that pepper and tomato plants show significant increase in height when grown in soil amended with BC under stress conditions. On the other hand, integrated Mix4 with PRD ($PRD_{50\%ETC}$ and $PRD_{75\%ETC}$) also showed significant influences on leave number during flowering and fruit setting stage. However, the previous treatment followed by CO4 under control treatment ($PRD_{75\%ETC}$) only exhibited their higher influences on stem diameter in flowering and fruit setting, and vigorous fruit bearing stage. On the contrary, the effect of PRD ($PRD_{50\%ETC}$) application on plant growth traits was more markedly on non-biochar or non-compost (control) plot, particularly during two later stages (Figure ***6***). The reduction in plant height and stem diameter under $PRD_{50\%ETC}$ during these two periods might be attributed to the reduction in cell turgor which would led to inhibition of cell division and cell expansion (A'fifah *et al*., 2013) [6].

3. Fresh and dry weight partitioning

Differences in partitioning plant parts were significant with PRD treatment, plants under $PRD_{50\%ETC}$ had a tendency for higher reduction in fresh weight and dry matter partitioning of the root, stem, leaf and fruit compared to plants under $PRD_{75\%ETC}$ treatment (Figure 7).



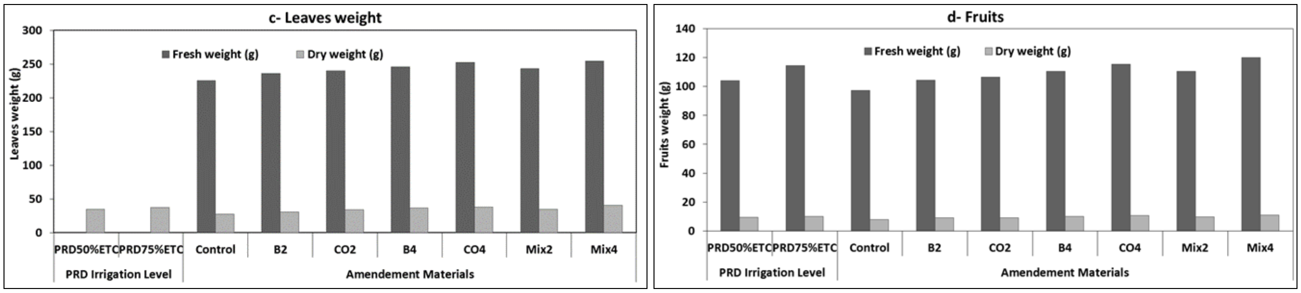


Fig 7: Effects of PRD water treatment and biochar, compost and their mixture on fresh and dry weight roots, stem and leave of bell pepper plants

Since, the root, stem, leaf, and fruit fresh and dry weights of bell pepper plant were reduced by (5.98%, 10.29%), (3.30%, 4.56%), (4.57%, 7.28%), and (9.31% and 4.82%), in that order. These results indicated that development of whole plant organs was closely related to the amount of irrigation water applied. The least reduction in dry weight under $PRD_{50\%ETC}$ was recorded in fruit only in comparison with other plant parts. This result can be explained by Ismail (2012) [5] who indicated that water movement into fruit may have reduced with progressive development of water deficit without affecting the translocation of dry matter into the fruit. In general, these significant differences in both fresh and dry weights in all parts with PRD treatment ($PRD_{50\%ETC}$) in the root environment can be clarified on the basis that pepper plants were grow under degree of water stress (Abdel-Mawgoud *et al*., 2005) [2]. Similarly, Mardani *et al*. (2017) [36] reported that vegetative growth of pepper was closely linked to the quantity of water applied, and the pepper physiological responses to DI were completely negative. Therefore, the above-mentioned results confirmed that bell pepper Sonar cultivar is sensitive to water stress as reported before (Shao *et al*., 2010; A'fifah *et al*., 2015) [50, 5].

Application of Biochar, especially at the high application rate (4%), increased the root fresh/dry weights followed by Mix4. However, Mix4 followed by high application rate of CO4 resulted in increases stem, leaf and fruit fresh/dry weights (Figure 7). Improved water relations in biochar-treated plants might be supported such increments in fresh/dry weights (Vaccari *et al*., 2015) [56]. Thus, it has been suggested that the ability of high rates of pyrolyzed date palm biomass (biochar) to enhance soil water availability may be partly responsible for increasing both fresh/dry weights of bell pepper plant parts (Thomas *et al*., 2013; Usman *et al*., 2016) [53, 55]. Control treatment adversely influenced either fresh or dry weight of all separated plant parts, as indicated by the lowest significant values of root, stem, leaf and fruit fresh/dry weights. A possible explanation is that the biochar improves SOC, soil pH, CEC, total N, C, P, and porosity, WHC, nutrient retention, and lowers SBD and tensile strength to facilitate plant growth due to improved root growth and higher nutrient uptake and in final, increase biomass accumulation (Scotti *et al*., 2015; Hussain *et al*., 2016; Trupiano *et al*., 2017) [25, 54]. According to Diacono and Montemurro (2011) [17] and Trupiano *et al*. (2017) [54] in compost amended soil, lettuce plants showed the maximum total biomass accumulation, probably due to the high soil nutrients availability (soil total C, N, P, and available P content) was increased.

There were significant differences of organic soil amendments with PRD treatments on either fresh or dry weights of all plant parts, but with different trends (Figure 8).

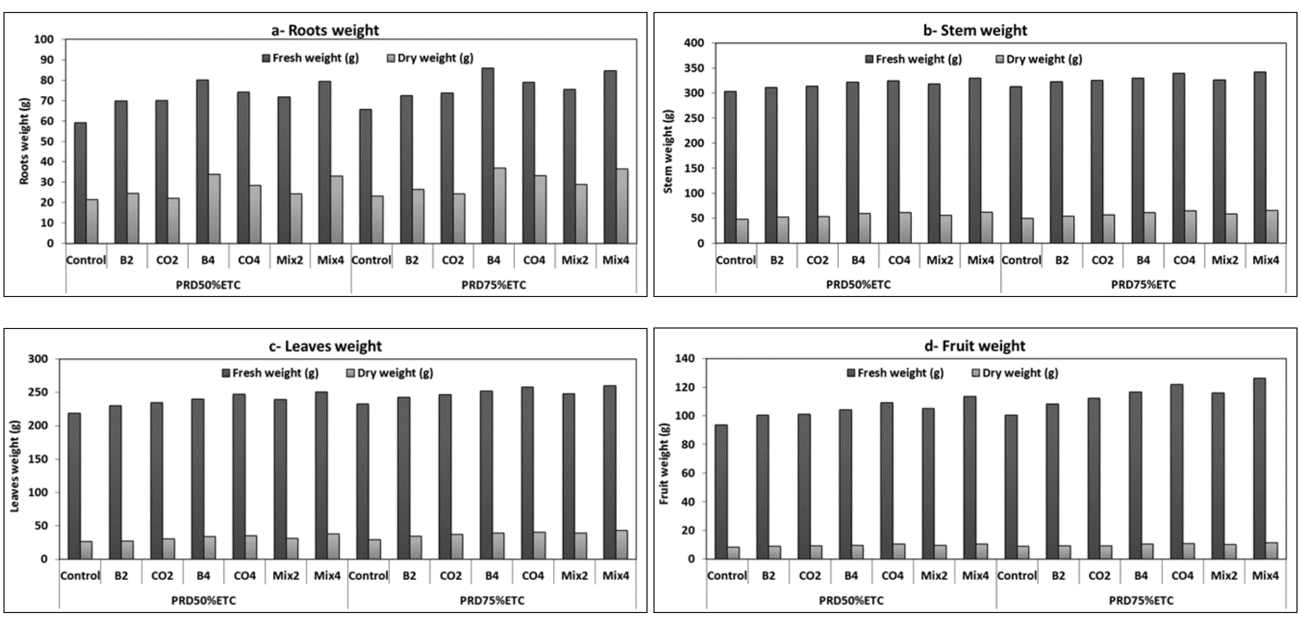


Fig 8: Combined effects of PRD water treatment and biochar, compost and their mixture on wet and dry weight of roots, stems, leaves and fruits of bell pepper plants

For instance, dry weight of the root was significantly affected by the high rate of B4 with either $PRD_{75\%ETC}$ (75% ETc) or $PRD_{50\%ETC}$ (50% ETc) treatments. This means that biochar was more effective on root dry weight trait over than PRD treatment. The stem and fruit dry weights were affected by Mix4 followed by CO4 with $PRD_{75\%ETC}$ and $PRD_{50\%ETC}$ (Figure 8).

We can explain that based on higher photosynthesis, since photosynthesis is a function of leaf area (Abdel-Mawgoud *et al*., 2005) [2]. Leaf area was found to be higher, particularly under these treatments (Figure 9).

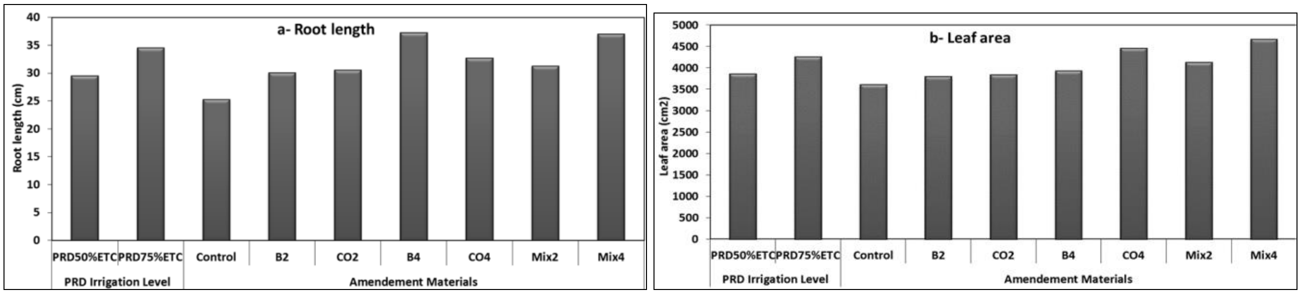


Fig 9: Effects of PRD water treatment and biochar, compost and their mixture on root length and leaves area of bell pepper plants

On the other hand, Mix4 followed by CO4 with only $PRD_{75\%ETC}$ resulted in the highest values of leaf dry weight. Similar to the response of the leaf dry weight trait, stem, leaf, and fruit fresh weight, were improved as a result of increase in the amount of water ($PRD_{75\%ETC}$) and Mix4 followed by CO4 applied. Schulz *et al*. (2014) reported that addition of compost to soils increases the pH and makes nutrients more available. Increased fresh weight partitioning in bell pepper plant was derived from the effects of optimum amount of water and Mix4 or CO4 applied to the plants. Therefore, it promoted better allocation of fresh weight to stem, leaf and fruit. On the other side, B4 followed by Mix4 under $PRD_{75\%ETC}$ produced the highest value of root fresh weight (Figure 8). This indicates that the root fresh weight was improved with feeding plants with high rate of biochar (B4) or Mix4 as a result of increasing the amount of water applied.

4. Root characteristics

The effect of PRD treatment on root fresh and dry weights, and length is shown in figures 8 and 9. Root length, and fresh and dry weights were significantly reduced with $PRD_{50\%ETC}$ treatment. The percentage of reduction in both fresh and dry weights was 5.98% and 10.29%, respectively (Figure 8), whereas a reduction in the root length was 14.69%, as compared with the control ($PRD_{75\%ETC}$) treatment (Figure 9). These results were in agreement with Ahmed *et al*. (2014) [10] who found significant decreases in root growth characters (length, fresh and dry weights) of hot pepper as a result of increasing DI water. The above analysis can be attributed to the impact of water as a vital component for root growth and development.

Organic soil amendments showed clear significance values in their effects on root characteristics (Figure 7, 8, 9&10). Applied higher rates of B4 followed by Mix4 increased bell pepper root fresh and dry weights (Figure 7&8), and root length (Figure 9&10) in comparison with other amendments. The control treatment registered the lowest significant values of root characteristics. Soil application with biochar has many advantages over the use of compost, for instance, it is a porous material with a high inner surface area which helps to retain more water and increase saturated hydraulic conductivity of soil (Dispenza *et al*., 2016) [18]. In this study, the structure of date palm biochar is derived from high temperature pyrolysis (400-450°C ± 10°C), it is characterized by a large surface area and aromatic-carbon content, which may improve the adsorption capacity and water retention ability plus porosity and carbon sequestration (Jindo *et al*., 2014; Akhtar *et al*., 2014; Hafeez *et al*., 2017) [30, 12, 23], that may help roots to reach more vigor.

The interaction influences of soil organic amendments and PRD treatments on root characteristics (root fresh and dry weights, and length) showed clear superior with B4 followed by Mix4 under $PRD_{75\%ETC}$ in comparison with other treatments under $PRD_{50\%ETC}$ (50% ETc) as shown in figure 8 and 10. This would approve a direct biochar role in the nutrient supply to plant roots (Trupiano *et al*., 2017) [54]. It is interested to found that control treatment with $PRD_{50\%ETC}$ detected the lowest significant value of root length (Figure 10).

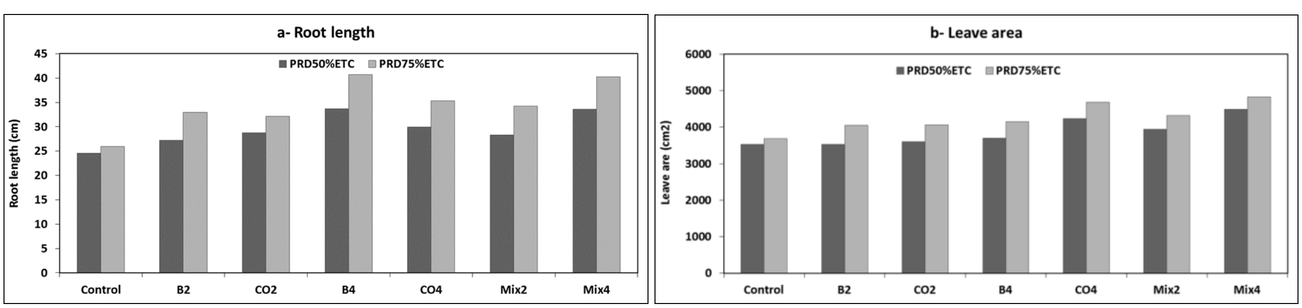


Fig 10: Combined effects of PRD water treatment and biochar, compost and their mixture on root depth and leaves area of bell pepper plants

Since, under water deficit conditions plant has to absorb water from deep soil so, it develops long roots (Ngugi *et al*., 2003; Nahar and Gretzmacher, 2011) [41, 40]; the results of this study did not support this tendency. Whereas, BC improves the water holding capacity of the soil so, root does not need to grow longer, as water is easily available to the plant (Yu *et al*., 2013; Hafeez *et al*., 2017) [23].

Conclusions

The positive impact of the biochar-compost mixture amendments together on bell pepper plant growth and productivity in addition to increase WUE allows more consideration on the feasibility of organic supplemented as a helpful cultural practice for production bell pepper grown under greenhouse conditions with PRD treatment. It is possible to increase pepper production, improve the WUE with saving irrigation water throughout integrated biochar-compost mixture application. In conclusion, the integration of biochar and compost along with (from $PRD_{75\%ETC}$ to $PRD_{50\%ETC}$) DI can be considered as a viable approach that improves bell pepper crop productivity, chlorophyll, growth parameters and promotes WUE (saving about 32% of water applied). This aspect is essentially prerequisite demand in arid areas, where water shortage is an increasing concern and water costs are frequently raising.

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