IMPROVING MOISTURE DISTRIBUTION PATTERN BY USING SOME SOIL CONDITIONERS IN LOAMY SAND SOIL UNDER DRIP IRRIGATION SYSTEM

M. H. M. Fayed¹ and M. H. M. Sheta²

ABSTRACT

A field experiment was carried out to study the conditioning effect of composted rice straw biochar (RSB) and synthetic cellulose polymer like carboxymethyl cellulose (CMC) on soil moisture distribution patterns, some plant growth parameters, yield and water use efficiency of squash plant (Cucurbita pepo L. var. Hybrid Revera). So, a complete randomized field experiment with three replications was conducted during the summer season of 2018 on a loamy sand soil at the Animal Production farm, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt. The treatments were applying RSB by two rates (i.e. 840 and 1680 kg fed⁻¹) and CMC by two rates (i.e. 16.8 and 33.6 kg fed⁻¹) with 100% and 80% of squash water requirements. The obtained results indicated a positive effect on soil moisture distribution patterns, some plant growth parameters, yield and water use efficiency due to application of RSB with 100 and 80% of squash water requirements. Whereas, the soil was retained by the highest moisture content (18.8-15.0%) and (15.4-10.6%) with 100% and 80% at (0-40cm), respectively. The highest productivity was 7576.69 and 6436.69 kg fed⁻¹ when adding 100% and 80% of squash water requirements, respectively. Also, the highest irrigation water use efficiency was 9.33 and 9.91 kg m⁻³ of irrigation water when adding 100% and 80% squash water requirements, respectively. Finally, the obtained results indicate that adding rice straw biochar (RSB) to the planting medium at a low water irrigation rate of 80% increases the efficiency of water use by preventing applied moisture from infiltrating beyond plant root zones and maximizing the amount of applied water available for plant uptake.

INTRODUCTION

Poor fertility (low water and nutrient retention capacity) and limited crop productivity characterize sandy soils in Egypt. One of the vital tasks in the Egyptian farming system is the search for natural organic modifications to improve their fertility.

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The addition of biochar as organic modification has become one of the practical strategies in recent years to improve the fertility of soil and the production of crops. Soil organic matter is highly oxidized and degraded in arid and semi-arid regions, so improving soil organic matter content gains considerable attention to maintaining soil quality and productivity under these conditions (Lal, 2008 and Papathanasiou et al., 2012). Adding organic residues to sandy soils is an environmentally friendly, cost-effective and common practice and is still a desirable way to improve their fertility. As an important management strategy, crop residues can be used to enrich the soil with nutrients through its decomposition and maintain soil fertility and crop production. Farmers, however, do not know the best ways to manage such residues as rice straw and are usually burned to clean the fields after harvesting. Thus, it becomes a vital task to search for a good way to recycle crop residues through biochar production. Recently, the recycling of organic residues through the process of thermal modification to produce the biochar as a soil conditioner is considered a beneficial and popular approach to soil improvement (Chan et al., 2008; Bonelli et al., 2001 and Mohamed et al., 2015).

Biochar properties are usually dependent on the type of biomass materials and pyrolysis process conditions (Singh et al., 2010). In many researches, it has been shown that biochar plays an important role in maintaining high soil fertility and can also improve soil carbon sequestration (Chan et al., 2008; Lehmann et al., 2008 and Ali, 2011a).

Carboxymethyl cellulose (CMC) is a cellulose-derived ester, caused by the reaction of cellulose with sodium hydroxide and sodium monochloroacetate, resulting in a long anhydroglucose chain, which in turn produces a highly hygroscopic and viscous polymer that is non-toxic to humans (Sanz et al., 2005). As the raw material is wood or cotton linters, CMC is produced from cellulose and is therefore based on a sustainable raw material. Cellulose is not water-soluble, but CMC is made water-soluble due to a chemical reaction in the presence of sodium hydroxide between cellulose and monochloroacetic acid. This reaction takes place in an aqueous system of alcohol (Adel et al., 2010). CMC as an amylose with many hydroxyl and carboxylic groups can absorb water and moisture, which means that the hydrogel made of it has many excellent
properties, such as high-water content, good biodegradation and a wide low-cost source (Nie et al., 2004).

This study aim to identifying the effect of treating a loamy sand soil with rice straw biochar (RSB) and hydrogel polymer i.e. carboxymethyl cellulose (CMC) individually at applied different rates on soil water distribution pattern, growth parameters, squash marketable yields and water use efficiency at applying 100 and 80% of squash water requirements.

**MATERIALS AND METHODS**

The main objectives of this study were improving the properties of loamy sand soil to increase their ability to retain soil moisture in the root zone for long periods under drip irrigation system. The experiment was laid out in completely randomized block design with three replicates for each treatment was conducted. The factorial randomized block design having two factors each and two additional control. Biochar and hydrogel were the two factors. Two levels of biochar $RSB_{100}$ - 100 g/plant pit i.e. 840 kg fed$^{-1}$, $RSB_{200}$ - 200 g/plant pit i.e. 1680 kg fed$^{-1}$ and two levels of carboxymethyl cellulose $CMC_{2}$ - 2 g/plant pit i.e. 16.8 kg fed$^{-1}$, $CMC_{4}$ - 4 g/plant pit i.e. 33.6 kg fed$^{-1}$, and two control treatments without RSB or CMC. The applied irrigation water for one of the control treatments was 100% of squash water requirements ($812 \, m^3 \, fed^{-1}$) which calculated by evaporation pan method and 80% of squash water requirements ($650 \, m^3 \, fed^{-1}$) for the second control treatment and other treatments.

**Soil conditioners**

1) **Preparation of biochar**

The biochar was prepared from the experimental farm of the Department of Agronomy, Faculty of Agriculture, Al-Azhar University) Nasr City, Cairo, Egypt, through the collection of the plant residues namely rice straw. The straw samples were air dried and cut to small pieces (1 - 2 cm), and then converted to biochar through the continuous low pyrolysis process at a temperature of 400 - 500°C for 30 min as a retention time (Lu et al., 2014). The obtained biochar was crushed and sieved to a fine size (< 2 mm) for the chemical analysis and experimental using. **Table (1)** show the chemical characteristics of biochar samples.
2) Carboxymethyl cellulose

The carboxymethyl cellulose (CMC) absorbent material used is produced under controlled conditions by reaction between alkali cellulose and sodium monocholora acetate. Formulation \((C_6H_{10}O_5)_n\), molecular weight \((162.2)n\) \(g\) \(mol^{-1}\) and elements \((C = 44.4\%,\ H = 49.4\) and \(O = 6.2\%)\). Cellulose is also a water - insoluble plant - based polymer such as wood (eucalyptus, poplar, pine) or cotton. The molecule of cellulose consists of many rings of glucose anhydride connected in the formation of a chain. There are 100 to 6000 glucose anhydride units in each polymer chain. CMC is the cellulose ether with the most water solubility (Adel et al., 2010 and Ali, 2011a).

Soil characteristics

Some physical and chemical characteristics of the soil at the experiment field at the farm of Animal Production Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt, were studied. Four soil samples were taken to represent the area of study, dug deep down to 30 cm depth. The samples were air dried, ground and sieved through a 2 mm screen to get the fine soil which is kept for analysis. The soil characteristics were measured in the Laboratory of Soils and Water Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt. Physical and chemical characteristics of the studied soil before planting were presented in Tables (2) and (3) which was determined according to Klute (1986) and Page et al., (1982).

Drip irrigation network

The field was plowed, disked, and leveled. The plot area was 10.5 \(m^2\) (length of 3.5 \(m\) and 3 \(m\) of width) i.e. 1/400 fed. The drip irrigation network was designed at the experimental field. The lateral line spacing was 1 \(m\) (one lateral for planting row). Emitter spacing on the lateral line was 0.5 \(m\) and the discharge rate of emitter was 4 \(l\) \(h^{-1}\). The irrigation intervals were 3 \(days\). The plant area, plant length, plant leaves number and production were measured for each treatment at all growth stages (initial, develop, mid and late stages).
Indicator crop
Squash plants (*Cucurbita pepo* L. var. Hybrid Revera) were grown in 27th April to 29th July 2018. The mineral fertilizers were added to the soil of experimental area according to the instruction and recommendations of Agriculture Research Center. FAO (1998) gives general lengths for the four distinct growth stages and total growing period for Squash of climates and locations. This data as shown in Table (4). Only three values of Kc are required to describe and construct the crop coefficient curve, those during the initial stage ($K_{C_{ini}}$), the mid-season stage ($K_{C_{mid}}$) and at the end of the late season stage ($K_{C_{end}}$) as in Table (5).

**Determination of squash water requirements**
Water irrigation requirements were calculated by the following equations:

$$ET_o = E_{pan} \times K_{pan} \quad (1)$$
$$ET_c = ET_o \times K_c \quad (2)$$
$$IWR = ET_c \times A \times F \quad (3)$$

Where:

- $ET_o$ : Potential evapotranspiration, ($mm \ day^{-1}$),
- $E_{pan}$ : Pan evaporation, ($mm \ day^{-1}$),

**Table (2): Physical properties of soil under study**

<table>
<thead>
<tr>
<th>Particle size distribution (%)</th>
<th>Textural class</th>
<th>Bulk density ($Mg \ m^{-3}$)</th>
<th>Total porosity (%)</th>
<th>OM ($g kg^{-1}$)</th>
<th>Moisture content (%) at:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>Fine sand</td>
<td>Silt</td>
<td>Clay</td>
<td>Loamy Sand</td>
<td></td>
</tr>
<tr>
<td>10.12</td>
<td>73.80</td>
<td>7.91</td>
<td>8.17</td>
<td>1.67</td>
<td>36.98</td>
</tr>
</tbody>
</table>

1Organic matter content, 2Field capacity, 3Permanent wilting point and 4Available water

**Table (3): Chemical properties of soil under study**

<table>
<thead>
<tr>
<th>pH (1:2.5)</th>
<th>EC (dS m$^{-1}$)</th>
<th>Cations (mmol c$^{-1}$)</th>
<th>Anions (mmol c$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.01</td>
<td>1.69</td>
<td>Ca$^{2+}$</td>
<td>Mg$^{2+}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.29</td>
<td>2.16</td>
</tr>
</tbody>
</table>

1:2.5 w/v soil water suspension and 2Soil paste extract

**Table (4): Lengths of crop development stages for various planting periods and climatic regions (days), (FAO, 1998)**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Initial ($L_{ini}$)</th>
<th>Develop ($L_{dev}$)</th>
<th>Mid ($L_{mid}$)</th>
<th>Late ($L_{late}$)</th>
<th>Total days</th>
<th>Planting date</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squash, Zucchini</td>
<td>25</td>
<td>35</td>
<td>25</td>
<td>15</td>
<td>100</td>
<td>April; Dec</td>
<td>Mediterranean &amp; Arid</td>
</tr>
</tbody>
</table>
Table (5): Single crop coefficients ($K_c$) and mean maximum plant heights ($m$) for non-stressed and well managed crop, (FAO, 1998)

<table>
<thead>
<tr>
<th>Crop</th>
<th>$K_c_{ini}$</th>
<th>$K_c_{mid}$</th>
<th>$K_c_{end}$</th>
<th>Maximum crop height &quot;$h&quot;$, (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squash, Zucchini</td>
<td>0.5</td>
<td>0.95</td>
<td>0.75</td>
<td>0.3</td>
</tr>
</tbody>
</table>

$K_{pan}$ : Pan coefficient from FAO tables 1998 were the wind speed and relative humidity in the experimental site was 12 m $s^{-1}$ and 50% respectively.

$ET_c$ : Crop evapotranspiration, ($mm\ day^{-1}$),

$K_c$ : Crop coefficient from table (5),

$IWR$ : Amounts of applied irrigation water, ($l\ Irri.\ day^{-1}$),

$A$ : Plant area, ($m^2$) and

$F$ : Irrigation frequency, (3 days).

**Determination of water application time:**

The water application time was calculated as in the following equation:

$$I_t = \frac{IWR}{q} \quad (4)$$

Where:

$I_t$ : Water application time, (h) and

$q$ : Emitter discharge, ($l\ h^{-1}$).

**Soil moisture content "$\theta_w$"**

To determine the soil moisture content before irrigation, the soil section was made under emitter directly and the soil samples were taken at different points on horizontal and vertical directions as in Fig. (1). After two hours of irrigation the soil samples were taken from the same section of wetting front advance at different points on horizontal and vertical directions. Soil moisture content was conducted by weighing a mass of wet soil samples, drying the soil for 24 h at 105°C, and then reweighing the samples. Water content was calculated by gravimetric method (mass of water divided by the mass of dry soil) by using the following equation (Ali, 2011b):

$$\theta_w = \frac{m_{water}}{m_{dry\ soil}} = \frac{m_{wet\ soil} - m_{dry\ soil}}{m_{dry\ soil}} \quad (5)$$

Where:

$\theta_w$ : Gravimetric water content, ($g\ g^{-1}$),

$m_{water}$ : Mass of water, ($g$),

$m_{dry\ soil}$ : Mass of soil after drying, ($g$) and

$m_{wet\ soil}$ : Mass of soil before drying, ($g$).
To illustrate soil moisture distribution patterns in different depths of investigated soil under drip irrigation system at different treatments, contour plots were constructed in figures using graphic software package Surfer®15 (2018). The contour lines obtained by Kriging (Gridding Method), show the radial locations of equal moisture content percentages within the wetted soil volume.

**Irrigation water use efficiency ''IWUE''**

Irrigation water use efficiency in \((kg\ m^{-3})\) was calculated using the following formula according to Payero et al., (2008).

\[
IWUE = \frac{Yield\ (kg\ fed^{-1})}{ETc\ (m^3\ fed^{-1})}
\]

where:

- \(IWUE\): Water use efficiency, \((kg\ m^{-3}\ water\ applied)\),
- \(Y\): Yield, \((kg\ fed^{-1})\) and
- \(ETc\): Seasonal crop evapotranspiration, \((m^3\ fed^{-1})\).

**Fig. (1):** A view showing the soil sampling points in the horizontal and vertical directions in the soil profile under the emitter directly.

**RESULTS AND DISCUSSION**

**Soil moisture distribution pattern**

Soil moisture distribution patterns of loamy sand soil profile as affected by different treatments were studied by soil moisture determination. **Fig. (2)** show the soil moisture distribution pattern before irrigation and after two hours of irrigation by 100% of squash water requirements due to the different treatments.
Before Irrigation

After Irrigation

**Fig. (2):** The soil moisture distribution pattern in the loamy sand soil between two emitters before irrigation and after two hours of irrigation at applying 100% of crop evapotranspiration under different treatments.
The results show that the soil under $RSB_{200}$ retained the highest values of moisture ($18.8 – 15\%$) at $(0 – 40 \text{ cm})$, respectively followed by $CMC_4$ ($17.6 – 13.8\%$), $RSB_{100}$ ($16.8 – 12.6\%$) and $CMC_2$ ($16.0 – 12.8\%$). Generally, all treatments were higher than control treatment ($15.4 – 10.6\%$). This may be due to the beneficial effect of soil conditioners for moisture retention in soil. These results agree with those of Johnson and Veltkamp (1985).

**Fig. (3)** show the soil moisture distribution pattern before irrigation and after two hours of irrigation by 80\% of squash water requirements due to the different treatments. The results show that the soil under $RSB_{200}$ retained the highest values of moisture ($15.4 – 10.6\%$) at $(0 – 40 \text{ cm})$, respectively followed by $CMC_4$ ($14.6 – 9.2\%$), $RSB_{100}$ ($14.4 – 9.6\%$) and $CMC_2$ ($13.8 – 9.8\%$). Generally, all treatments were higher than control treatment ($13.6 – 9.8\%$). This may be due to the beneficial effect of soil conditioners for moisture retention in soil. These results agree with those of Johnson and Veltkamp (1985).

**Squash growth parameters**

Figs. (4) and (5) show the relation between growth parameters; plant area "$PA" (cm$^2$), plant length "$PL" (cm) and plant leaves number "$PLN" (unit) in squash growth stages (ini., dev., and late stages) at different treatments when applying 100\% and 80\% of squash water requirements, respectively. The results reveal that the great values of plant area, plant length and plant leaves number in the growth stages of squash crop (ini., dev., and late stages) were obtained after of $RSB_{200}$ treatment either irrigated 100\% or 80\% from squash water requirements.

**Squash marketable yields "$Y" (kg fed$^{-1}$)**

**Fig. (6)** illustrate that, the marketable yields of squash were increased due to the application of different conditioners and rates by 6.92, 2.25, 3.91 and 0.18\% for $RSB_{200}$, $RSB_{100}$, $CMC_4$ and $CMC_2$, respectively compared to the control treatment (non-conditioned soil) which recorded 7086.27 kg fed$^{-1}$ when irrigated by 100\% of squash water requirements.

Concerning the effect of different treatments on squash marketable yield after irrigation by 80\% from water requirements, **Fig. (7)** illustrate that, the squash marketable yield were increased due to the application of the some previous conditioners and rates by 16.66, 4.14, 10.63 and 3.22\% for $RSB_{200}$, $RSB_{100}$, $CMC_4$ and $CMC_2$, respectively compared to the
control treatment which recorded 5517.46 kg fed⁻¹ irrigated by 80% of squash water requirements.

**Fig. (3):** The soil moisture distribution pattern in the loamy sand soil between two emitters before irrigation and after two hours of irrigation at applying 80% of crop evapotranspiration under different treatments.
Fig. (4): Relation between some growth parameters of squash after the different treatments with applying 100% of squash water requirements.
Fig. (5): Relation between some growth parameters of squash after the different treatments with applying 80% of squash water requirements.
Mass production \( y' \) \((kg fed^{-1})\)

**Fig. (6):** Relation between mass production \((kg fed^{-1})\) for the different treatments applying 100% of squash water requirements.

**Fig. (7):** Relation between mass production \((kg fed^{-1})\) for the different treatments applying 80% of squash water requirements.

These results may be due to effect of used conditioners in improvement of soil physical and chemical properties such as soil moisture retention,
available water, cation exchange capacity and subsequently increasing nutrients availability which is enhance of squash productivity. These results agree well with those of Ali, (2011a).

Irrigation water use efficiency "IWUE" (kg m⁻³)

Figs. (8) and (9) show the relation between squash production and the total seasonal water used at applying 100% and 80% of crop evapotranspiration, respectively.

From Fig. (8) the irrigation water use efficiency was increased due to application of these conditioners by 9.33, 8.92, 9.07, and 8.74 kg m⁻³ of seasonal irrigation water for RSB₂₀₀, RSB₁₀₀, CMC₄ and CMC₂, respectively compared to the control treatment (non-conditioned soil) which recorded 8.72 kg m⁻³ of seasonal irrigation water at applying 100% of squash water requirements.

Also, from Fig. (9) the irrigation water use efficiency was increased due to application of these conditioners by 9.91, 8.84, 9.39, and 8.76 kg m⁻³ of seasonal irrigation water for RSB₂₀₀, RSB₁₀₀, CMC₄ and CMC₂, respectively compared to the control treatment which recorded 8.49

**Treatments**

Fig. (8): Relation between irrigation water use efficiency "IWUE" (kg m⁻³) for the different treatments applying 100% of squash water requirements.
kg m\(^{-3}\) of seasonal irrigation water at applying 80% of squash water requirements.

Data show that treating the sandy soil with tested conditioners led to an increase in water use efficiency by growing plants (yield in kg m\(^{-3}\) of irrigation water used). These results agree well with those of Ali, (2011a).

![Water use efficiency graph](image)

**Treatments**

**Fig. (9):** Relation between irrigation water use efficiency \("IWUE"\) (kg m\(^{-3}\)) for the different treatments applying 80% of squash water requirements.

From the above-mentioned results, it's concluded that the advantage of \(RSB\) and \(CMC\) conditioners for conserving of irrigation water and increasing the agricultural potentialities of loamy sand soils, enhancing the crop productivity and increasing of water use efficiency.

**REFERENCES**


الملخص العربي
تحسين نمط التوزيع الرطوبى للتربة الرملية الطميية باستخدام بعض محسنات التربة تحت نظام الري بالتتنقيط

مصطفى حسن مصطفى فايداً و محمد حامد شتاً

غالبًا ما تكون إنتاجية التربة الرملية الطميية محدودة بسبب قدرتها المنخفضة على الاحتفاظ بالموائد وفقدانها بالتسرب العميق مما يقلل من كفاءة استخدام المياه والاسمادة بواسطة النباتات، لذلك يهدف هذا البحث إلى تحسين خصائص هذه التربة لزيادة قدرتها على الاحتفاظ بالمياه وتقليل فقدان المياه بالتسرب العميق والتبخر باستخدام بعض محسنات التربة مثل فحم قش الأرز وكربوكسي ميثيل سيليلوز. وتحقيق هذا الهدف أجريت تجربة في مزرعة قسم الإنتاج الحيواني - كلية الزراعة بالقاهرة - جامعة الأزهر. بنظام القطاعات الكاملة العشوائية مع ثلاثية مكررات لكل معاملة. وكانت معاملات التجربة كما يلي:

1) إضافة فحم قش الأرز RSB كمحتوى لخصائص التربة بمعدلين هما 100 و 200 جم/حيرة نبات وذلك مع الري بكامل الاحتياجات المائية 100 و 80 % لنباتات الكوسا.

2) إضافة كربوكسي ميثيل سيليلوز CMC كمحتوى لخصائص التربة بمعدلين هما 2 و 4 جم/حيرة نبات وذلك مع الري بكامل الاحتياجات المائية 100 و 80 % لنباتات الكوسا.

مدرس بقسم هندسة نظم المياه والري – كلية الهندسة الزراعية بالقاهرة – جامعة الأزهر.

مدرس بقسم الأراضي والمياه – كلية الزراعة بالقاهرة – جامعة الأزهر.

Misr J. Ag. Eng., October 2018 - 1325 -
معاملات كنترول بإضافة 100% و 80% من الاحتياجات المائية للنباتات، وبدون أي إضافات للترطيب من محسنات التربة المستخدمة سابقاً.

تم زراعة نباتات الكوسة صنف ريفيرا في الفترة من 27/4/2018 إلى 29/7/2018م تحت نظام الري بالتنقيط، وتم أخذ القياسات التالية:

1) تم قياس المحتوى الرطب في التربة أفقياً على أبعاد الصفر و 25 و 50 سم من النقطة أو النباتات - ورأسيًّا على أبعاد الصفر و 40 و 60 سم من سطح التربة.

2) تم قياس بعض الصفات الخضرية للنباتات وهي: مساحة النباتات وطول النباتات وعدد أوراق النباتات في مراحل نمو النباتات المختلفة وأيضًا تقييم الإنتاجية لكل معاملة ومن ثم حساب كفاءة استخدام المياه لكل المعاملات.

قد أشارت النتائج المتحصل عليها بصورة عامة إلى تأثير إيجابي واضح على بعض مقاييس النمو لنبات الكوسة (مساحة النباتات، طول النباتات، عدد الأوراق) في جميع مراحل النمو للنباتات والإنتاجية في نهاية الموسم، وكذا كفاءة الاستخدام لمياه الري لكل النوع من محسنات التربة المستخدمة، فحم قش الأرز وكربوكسي ميثيل سيلولوز عند إضافة 100% و 80% من الاستهلاك المائي للنباتات.

وقد أعتمدت النتائج على معدل الإضافة من المحسنات المستخدمة وكان تأثير فحم قش الأرز على المحمول لنبات الكوسة أعلى من كربوكسي ميثيل سيلولوز - وكانت أهم النتائج المتحصل عليها كما يلي:

1) أفضل نمط للتوزيع الرطب في منطقة الجذور كان عند إضافة فحم قش الأرز للتربة بمعدل 200 جم/جورة نبات حيث كان المحتوى الرطب في التربة في منطقة الجذور (صفر – 40 سم أدنى سطح التربة) بعد الري بساعتين أعلى دائمًا من السعة الحقلية للترطيب (13.5%) حيث كان يتراوح بين 18.8% - 15.4% و 15% - 10.6% عند إضافة 100% و 80% من الاستهلاك المائي للمحمول على الترتيب وذلك يهيئ بيئة مثلى لنمو الجذور من حيث توازن الماء والهواء في التربة.

2) أعلى إنتاجية كانت عند إضافة فحم قش الأرز للتربة بمعدل 200 جم/جورة نبات حيث كانت الإنتاجية 7576.49 و 6436.69 كجم/فدان وذلك عند إضافة 100% و 80% من الاستهلاك المائي للنباتات على الترتيب.

3) أعلى كفاءة استخدام لمياه الري كانت عند إضافة فحم قش الأرز للتربة بمعدل 200 جم/جورة نبات حيث كانت 9.33 و 9.91 كجم/م³ من مياه الري وذلك عند إضافة 100% و 80% من الاستهلاك المائي للنباتات على الترتيب.

وأخيرًا، يمكن استنتاج أنه بإضافة فحم قش الأرز للتربة بمعدل 200 جم/جورة نبات وإضافة 100% من الاستهلاك المائي للنباتات فإن ذلك يزيد من كفاءة استخدام المياه حيث أنه يمنع فقد الرطوبة من التربة بالتسرب العميق ويزيد من تدفق الماء للنباتات. 