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(RESEARCH ARTICLE)

Influence of using different percentages decomposed rice straw as alternative substrate on celery plants

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Abstract

This paper focused on evaluating the effect of using different decomposed percentages of rice straw as alternative substrate on growth, yield and irrigation water use efficiency (IWUE) of celery plants. The experimental layout was in the experimental farm of Central Laboratory for Agricultural Climate and the design was randomized complete block with three replications. Celery seedlings (cv. Green giant) were transplanted in 1st of December, 2017/2018 and 2018/2019. Four ages (levels of decomposed) of rice straw were used (new rice straw, old rice straw 3 months, old rice straw 6 months and old rice straw 9 months) as a substrate in this investigation compared to clay soil. Results indicated that using the old rice straw, 6 months substrate recorded a moderate substrate temperature. Plant length, N, P, soluble sugar content and yield were not affected by cultivated celery plants in clay soil or old rice straw 6 months as substrate. whereas, plant diameter, chlorophyll reading, K and vitamin C content were affected negatively by using different percentages decomposed rice straw as alternative grown substrate. On the other hand, irrigation water use efficiency (IWUE) enhanced by cultivated celery plants in clay soil and old rice straw 6 months substrate.

Keywords: Celery; Rice Straw; Decomposed; Irrigation water use efficiency (IWUE).

1. Introduction

Rice is one of the major foods, with consumption per capita of 65 kg per year, accounting for 20% of global ingested calories. Rice production is expected to increase significantly in the near future to feed the rising human population. Today, paddy rice culture produces 660 million tons of rice, along with 800 million dry tons of agricultural residues [1], mainly straw, a fact which makes rice straw one of the most abundant agricultural residues by products available in large quantities.

Only 20% of the annual production is used for purposes, such as ethanol and paper production [2], and the remaining, 80% is left on the field or burning, which contributes in global warming and atmospheric pollution [3].

Rice straw is a lingo-cellulosic material consisting predominantly of celluloses and hemi-celluloses (more than 60 percent) in addition to lignin's (15 to 20 percent), water-soluble substances (5 to 12 percent), mineral matter or ash and proteins which are usually present in very small amounts (2.2 to 3.0 percent), [4]. In addition, rice straw contain high nutrient value from (nitrogen, phosphorus, sulfur and potassium), which can use as a source for very high nutrient value as well as supplies organic matter for N fixation by heterotrophic N-fixing microorganisms, which could be absorbed by succeeding crop [5], [6].

In Egypt, rice crop is consider the most important field crop, Egypt produce about 4.5 million tons of rice. Nowadays, there is a public awareness of burning agricultural residues, procedures leads to unacceptable air quality. This is partly

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brought about by recent reports on what is locally known as “the Black Cloud” in the environmental ecosystem. Probably the most prominent example of this is rice straw, of which in recent years nearly 3.7 million tons per year was burned in the field, creating both an economic waste and environmental problems [6].

The burning of crop residues in fields is one of the most significant activities of global biomass burning [7], and contributes substantially to air pollution. After harvesting, the rice straw waste is frequently burned in the open in regions with insufficient time before planting the next crop to remove and dispose of it in a more controlled manner, such as in a furnace or by using another closed burning technique [8]. In addition, some farmers believe that rice straw open burning can remove weeds, control diseases, and release nutrients for the next crop [9]. However, in contrast to closed burning, the open burning of rice straw is an uncontrolled combustion process in which the products of burning are emitted into the atmosphere, such as CO_2, CO, CH_4, particulate matter (PM), NOx, and SO_2, influencing both the local air quality and global climate [10], [11], [12], [13]. Furthermore, burning rice straw in fields may contribute to the emission of harmful air pollutants, such as Polycyclic Aromatic Hydrocarbons (PAHs), Poly Chlorinated Dibenzo Dioxins (PCDDs), and Poly Chlorinated Dibenzo Furans (PCDFs), threatening human health [14], [15], [16], [17].

On the other hand, growing media have three main functions: 1) providing aeration and water, 2) allowing for maximum root growth and 3) physically support the plant. Growing media should have large particles with adequate pore spaces between the particles [18].

Moreover, cultivated vegetable crops on compacted rice straw bales such as straw berry, pepper, tomato, cucumber and okra in open field or under greenhouse were promised method to utilize rice straw residues [19], [20]. In addition, the cultivation on compacted rice straw bales was used in the soil, which suffered from soil borne diseases and high salinity. The dynamic of decomposed rice straw characteristics throw the time and found that the mass, C/N ratio, N, P and K released for decomposed rice straw are changed dramatically throw the time in the short period [21].

Celery (*Apium graveolens* L.) is popular vegetable and aromatic plant grown mostly for its fresh herbs as salad crop in different parts of the world. Celery thrives best in climates with a long, cool growing season, especially at night. Optimum production occurs when mean temperatures range between 16 °C and 21 °C with the introduction of cultivars for tolerating upper temperature ranges. Celery can be produced in tunnel houses for early or late markets [22].

This study aims to investigate the effect of using different percentages decomposed rice straw as alternative grown substrate on celery plants growth quality and yield.

2. Material and methods

2.1. Experimental site

For evaluating superiority of rice straw different decomposition ages as a cultivation substrate for growing celery under greenhouse conditions, the current investigation was held on at research farm of the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation during seasons of 2017/2018 and 2018/2019. The geographical coordinate of the experimental site is 30°.00'.00" N and 31 °.140 '.00 " E.

2.2. Greenhouse preparation

The experiment was conducted under single tunnel greenhouse, 60 m long, 9 m width and 3.25 m height. The greenhouse was covered by white screen net. The total area of greenhouse was 540 m^2. It was divided into five ridge beds separated by pathway 0.60 m wide. Each ridge bed was 1 m width and 60 m long.

2.3. Plant material and culture circumstances

Celery seedlings (cv. Green giant) were transplanted to the used pots in 1st of December of 2017/2018 and 2018/2019 seasons. The spacing between plants inside the same raw was 0.5 m and the spacing between rows was 0.60 m. Twenty litters volume`s pots were used in this experiment as a cultivation containers. The pots were filled with both transferred soil and different ages of chopped rice straw media. In addition, a basic mix of compost and nutrients such as N, P, K and S (recommended doses) were applied under the last five centimeters of pots height and compacted by hand. The characteristics of the rice straw are shown in Table (1). All rice straw media were wetted by spraying water daily for one week before cultivation to keep the rice straw media at a proper moist. Used pots were irrigated using drip irrigation system in which the dripping line was placed above the pots about 5 cm from the center of the transplants.

Table 1 Characteristics of rice straw media

Characteristics	Value
Moisture content (%)	8.90
EC (dS/m)	3.5
pH	6.55
Organic matter (%)	80.25
Organic carbon (%)	77.56
Total N (%)	0.76
Total P (%)	0.63
Total K (%)	0.42
Ash (%)	12.3
Chemical available (mg / kg)	
N	896
P	474
K	465
C / N ratio	66 : 1

2.4. Treatments

Four ages (levels of decomposed) of rice straw were used as a substrate in this investigation compared to the soil as follow:

New rice straw (from the field). It was shredded to 2-4 inches using a grinder machine.

Three months rice straw (cultivated three months before).

Six months rice straw (cultivated six months before).

Nine months rice straw (cultivated nine months before).

Soil as a control.

The used soil was classified as sandy clay loam (Table 2).

Table 2 Characteristics of the soil used as control

Particle size distribution			**Texture**	**pH**	**EC dS/m**	**$CaCo_3$ (%)**	**Organic matter (%)**
Sand	Silt	clay					
57.3	16.7	26	Sandy clay loam	8.2	2.4	16.0	0.35
Soluble cations and anions (meq/l)							
Ca^{+}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}		
6.0	3.0	20.1	1.2	13.0	2.6		

2.5. Climatic measurements

In order to determine the climatic profile during the growing seasons, average soil temperature were manually recorded every day with occasionally exception. As well as, all temperature of all tested substrates were daily recorded at 10 cm depth in each treatment and in soil (control), it was recorded by using a digital thermo/hygrometer Art. No.30.5000/30.5002 (Produced by TFA, Germany). The obtained temperature values were averaged in order to create the temperature profile for each of the two growing seasons.

2.6. Recorded data

Data were recorded at the end of the growing seasons (after 90 days from transplanting) on plant length (cm), plant diameter (cm), chlorophyll (SPADE), soluble sugar (by the anthrone method, [23], vitamin C (by using the 2, 6 Dichlorophenol indophenol method described in Association of Official Analytical Chemists [24], nitrogen, potassium and phosphorus content in plants (%), (according to distillation in a Macro-Kjeldahle apparatus [25] and atomic absorption spectrophotometric [26] methods), and total yields as well as, average fruit weight were determinate.

2.7. Calculation of irrigation requirements

Irrigation requirements for celery plants was calculated based on crop evapotranspiration (ET_o) and the evapotranspiration under net-covered greenhouse conditions was estimated according to [27]. As follow:
$ET_{GH} = 0.7 \times ETo_{outside}$

Where:

ET_{GH} = the evapotranspiration under greenhouse conditions
$ETo_{outside}$= the evapotranspiration in the open field conditions
Drip irrigation system was used for irrigation which applied following the evapotranspiration (ETc) method according to soil water balance [28] as follows:
$ETc = ET_{GH} \times Kc$
Where:
ETc = the water requirements for celery plant under greenhouse conditions
ET_{GH} = the evapotranspiration under greenhouse conditions
Kc = the crop coefficient for celery plant

The Kc of celery plants was used according to [29], the Kc values were varied throughout different plant growth stages and increased from 0.7 (initial stage) to 1.05 (middle stage) from transplanting to the begging of harvest, and decreased again from 1.05 to 0.95 at the end of the growing season. The irrigation requirements for celery plants was calculated according to [29]**.** Drip irrigation was used from December 1^{st} up to the end of the growing season in 30^{th} of March. The total amount of irrigation water was estimated by water gauger and Table (3) shows the total amount of irrigation water for greenhouse area during both growing seasons.

Table 3 Irrigation water consumption amount for celery plants in both growing seasons

	L /plot / Month	
Period	2017-2018	2018- 2019
(1-31 Dec.)	557.500	557.500
(1-31 Jan.)	1346.600	1346.600
(1-28 Feb.)	3009.800	3009.800
(1-30 Mar.)	4809.400	4809.400
Total consumption (L / plot)	9723.300	9723.300
Total consumption (L / GH)	48616.500	48616.500
Total consumption (M3 / GH)	48.617	48.617

2.8. Irrigation Water use efficiency (IWUE)

Irrigation Water use efficiency was calculated for fresh yield of celery plant for different treatments according to [30], using the following equation

IWUE = Total yield (Kg) / Total water consumption (m^3).

2.9. Experimental design and data analysis

The experimental design was arranged in randomized complete block design with three replications.

The results obtained in each study variable were submitted to analysis of variance and Duncan's multiple range test ($P \leq 0.05$) for comparison of means, through STATISTICA version7 [31].

3. Results

3.1. Average rice straw substrate and soil temperature

Average substrate and soil temperature during 2017/2018 and 2018/2019 seasons was shown in Figure (1).

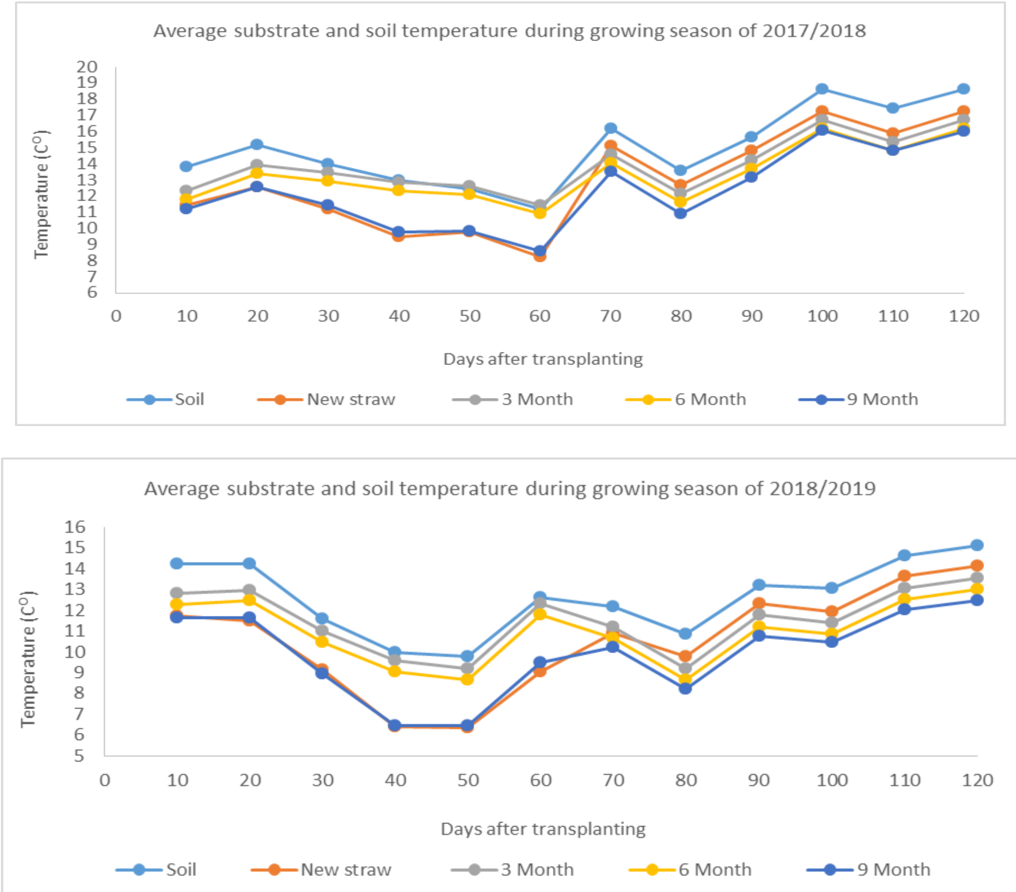

Figure 1 Average substrate and soil temperature during two growing seasons 2017/2018 and 2018/2019.

The illustrated data indicated that the control treatment (clay soil) had the highest value of the average soil temperature during the two tested seasons. Whereas, the new rice straw substrate was ranked the second and the old rice straw, 3 months substrate was the third highest temperature, (from the day eighty after transplanting to the end of the growing season). Focusing on the lowest substrate temperature, it was notable that both of the old rice straw substrate, 9 months and the new rice straw substrate were the lowest (semi similar values) starting from transplanting date until the day sixty. However, the second highest value was recorded in old rice straw 3 months substrate starting from the transplanting date until the day seventy. Generally, during the season period, the old rice straw substrate, 9 months was absolutely the lowest, and the 6 months rice straw substrate occupy the second lowest position. While, old rice straw 3 months substrate recorded a moderate of average substrate from the beginning to the end of growing season in both tested seasons.

Illustrated data in Table (4) showed effect of using different percentages decomposed of grown substrate on plant length, plant diameter and chlorophyll in celery plants, compared with clay soil.

3.2. Plant length

Data in Table (4) indicated that plant length was affected significantly by using different decomposition percentages of rice straw as a substrate. The greats values of plant length was obtained with clay soil treatment followed by old rice straw 6 months without any significant different between them. While, the lowest values of this parameter was recorded by new rice straw treatment. The same trend was observed in both growing seasons.

Table 4 Effect of using different percentages decomposed of rice straw substrate on plant length (cm), plant diameter (cm) and chlorophyll reading during 2017/2018 and 2018/2019 seasons.

Treatments	Plant length	Plant diameter	chlorophyll
	First season		
New rice straw	28.0 D	3.2 D	1.089 E
Old rice straw 3 months	35.2 B	4.4 C	1.233 C
Old rice straw 6 months	38.3 A	5.0 B	1.475 B
Old rice straw 9 months	31.4 C	3.9 C	1.138 D
Clay soil (Control)	38.8 A	5.7 A	1.503 A
	Second season		
New rice straw	27.4 D	3.1 C	1.088 E
Old rice straw 3 months	34.0 B	4.2 B	1.232 C
Old rice straw 6 months	37.2 A	4.9 A	1.473 B
Old rice straw 9 months	30.6 C	3.7 B	1.137 D
Clay soil (Control)	37.8 A	5.4 A	1.502 A

3.3. Plant diameter

Presented data in Table (4) showed that, plants which cultivated in the clay soil and the old rice straw, 6 months treatments gave the highest values of plant diameter. Whereas, cultivated celery plants in new rice straw was obtained the lowest values of this parameter. The same results were observed in the second season. Moreover, in the second season, noticed that there is no significant difference between the old rice straw, 3 months and 9 months decomposed period treatments.

3.4. Chlorophyll

Chlorophyll reading was affected significantly by using rice straw as a growing substrate. In Table (4) we found that using rice straw as a substrate lead to decreased chlorophyll reading at celery leaves. The highest chlorophyll reading was recorded in the plants which cultivated in clay soil followed by the old rice straw, 6 months treatment, respectively. Whereas, new rice straw treatment gave the lowest chlorophyll reading. This result was true at two tested seasons.

3.5. Nitrogen, phosphorus and potassium content in leaves

Data in Table (5) revealed the significant effect of different decomposed percentages of rice straw on celery leaves content of (N, P and K). The greatest leaves content of N, P and K were noticed at the clay soil and the old rice straw, 6 months treatments without any significant difference between them, except K content which gave a significant difference between the clay soil and other tested treatments. This trend was true in both growing seasons.

Table 5 Effect of using different percentages decomposed of rice straw substrate on celery leaves content of (N, P and K %) during 2017/2018 and 2018/2019 seasons.

Treatments	N	P	K
			First season
New rice straw	39.138 C	4.658 D	35.596 D
Old rice straw 3 months	43.187 B	8.518 B	43.019 C
Old rice straw 6 months	51.791 A	9.917 A	48.856 B
Old rice straw 9 months	41.905 B	5.764 C	41.197 C
Clay soil (Control)	53.545 A	10.530 A	55.975 A
			Second season
New rice straw	38.667 C	4.607 D	35.167 D
Old rice straw 3 months	42.667 B	8.423 B	42.500 C
Old rice straw 6 months	51.167 A	9.807 A	48.267 B
Old rice straw 9 months	41.400 B	5.700 C	40.700 C
Clay soil (Control)	52.900 A	10.413 A	55.300 A

3.6. Soluble sugar

Recorded data in Table (6) show the effect of different decomposed percentages of rice straw substrate and the clay soil on celery plants content of soluble sugar. The celery plants which cultivated in both the clay soil and the old rice straw, 6 months treatments were obtained the greatest content of soluble sugar, without any significant difference between them. However, plants grown in the new rice straw was indicated lowest content of soluble sugar. This result was indicated in the second season.

3.7. Vitamin C

Data in Table (6) obtained that cultivation in clay soil treatment increased the content of vitamin C in celery plants followed by the old rice straw, 6 months treatment which replaced second place. Moreover, using new rice straw as a substrate decreased vitamin C content in plants. Generally, using rice straw as a substrate led to reduce content of vitamin C in celery plant. The same trend was found in the second season.

Table 6 Effect of using different percentages decomposed of rice straw substrate on celery plants content of soluble sugar (%), vitamin C (%) and total yield (Kg) during 2017/2018 and 2018/2019 seasons.

Treatments	Soluble sugar	Vitamin C	Yield
	First season		
New rice straw	1.984 D	2.254 E	1133.3 D
Old rice straw 3 months	2.969 B	2.460 C	1275.0 B
Old rice straw 6 months	3.661 A	2.548 B	1376.6 A
Old rice straw 9 months	2.372 C	2.365 D	1203.8 C
Clay soil (Control)	3.789 A	2.656 A	1381.3 A
	Second season		
New rice straw	1.960 D	2.227 E	1130.0 D
Old rice straw 3 months	2.933 B	2.430 C	1271.7 B
Old rice straw 6 months	3.617 A	2.517 B	1373.0 A
Old rice straw 9 months	2.343 C	2.337 D	1201.3 C
Clay soil (Control)	3.743 A	2.623 A	1375.3 A

3.8. Yield

Celery plants yield was affected positively by decomposition percentage of rice straw in both tested seasons. Table (6). Obtained that yield had slightly increased by using the clay soil and the old rice straw, 6 months treatments without any significant differences between them. Whereas, using the new rice straw treatment led to reduce the celery yield. The same result was noticed in the second season.

3.9. Irrigation Water use efficiency (WUE)

Data in Table (7) show the effect of clay soil and different decomposition percentage of rice straw substrates on irrigation water use efficiency (IWUE) of celery plants. The highest values of IWUE was recorded for plants which cultivated in old rice straw, 6 months and the clay soil, 34 and 34.1, respectively in the first season and 33.9 and 34, respectively in the second season. In the contrary, the new rice straw substrate gave the lowest values of IWUE in both tested seasons. These results may be due to the physical characteristics of old rice straw substrate as well as clay soil which make both of them able to save sufficient available water for celery plants throw the growing season, so the plant able to grow well without any stress. On the contrary, the new rice straw and very old decomposed one have a poor characteristics and the plants which cultivated in suffering from insufficient water stress during the growing season.

Table 7 Effect of using different percentages decomposed of rice straw substrate on IWUE of celery plants during 2017/2018 and 2018/2019 seasons.

Treatments	Total yield (Kg / GH)	Total water consumption (M^3/ GH)	IWUE (Kg /M^3)
	Frist season		
New rice straw	1360.0	48.6	28.0
Old rice straw 3 months	1530.0	48.6	31.5
Old rice straw 6 months	1651.9	48.6	34.0
Old rice straw 9 months	1444.6	48.6	29.7
Clay soil (Control)	1657.6	48.6	34.1
	Second season		
New rice straw	1356.0	48.6	27.9
Old rice straw 3 months	1526.0	48.6	31.4
Old rice straw 6 months	1647.6	48.6	33.9
Old rice straw 9 months	1441.6	48.6	29.7
Clay soil (Control)	1650.4	48.6	34.0

4. Discussion

Open burning of rice straw causes release of air pollutants, which contributes to enhance climate change related issues. Moreover, the burning practice was a reason of losing carbon content from crop land to the atmosphere. Moreover, burning causes a loss of nutrients and organic matter. Not only is rice straw the major organic material available to rice farmers but is considerable amount of the macronutrients, namely nitrogen, phosphorus and potassium as well as important micronutrients like sulfur and silicon are contained in the rice straw [32], [33].

Rice straw is rapidly decompose material. Its high organic matter and low organic carbon concentration were adequate for the growth [34].

The variations in substrate temperature may be due to activates of micro-organisms, which improved biodegradation of rice straw. These ability to enhance biodegradation shows potential to fasten the decomposing period [35]. In addition, [36] observed that degradation of paddy straw with fungal cultures shows an increase and higher value of cellulose activity after day 30 of degradation process. Whereas, control treatment showed the lowest activity which is expected since no inoculant were present to boost the degradation process. On other hand, during degradation period, the composition of rice straw undergoes changes to much stable fraction. The amount of lignin, hemicellulose and cellulose composition in treatment with microorganisms are much lesser than the control rice straw [35]. This is similar to the finding by [37], where the decrease in composition of rice straw occurrence indicated the results of breakdown or hydrolysis of complex sugar into fermentable sugars.

The general observed of increasing vegetative growth characteristics such as (plant length, plant diameter and chlorophyll reading) particularly of using decomposed rice straw might be associated with nitrogen, phosphorus and potassium levels in the media, facilitated by faster rate of decomposition of rice straw and conversion into an assimilable form for plant uptake. The results indicated in this investigation are agreement with [38], [39], [40], whom mentioned that available more water enhances nutrient availability which improves nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to fruit. Also, using rice straw as a growing media help to improve the aeration of root then led to higher root zone and vegetative growth compared to cultivate in the soil [41]. However, the decrease in the growth at new rice straw might be due to the new rice straw takes more time to decompose for release of nutrients.

Other authors, reported decomposition of rice straw is responsibility of many type of microorganisms, i.e. bacteria and fungi [42], [43]. Fungi, i.e. *Aspergillus*, *Fusarium*, *Trichoderma*, *Chyptoga Mucor sp*. the main decomposer agents that can breakdown the rice straw [44]. Fungal inoculate can accelerate the decomposition of rice straw. *Trichoderma sp*. is the best indigenous fungi in the decomposition process of rice straw [45]. Plant growth promoting rhizobacteria (PGPR) are naturally occurring organic media bacteria that aggressively colonize plant roots and benefit plants by providing growth promotion. Inoculation of crop plants with certain strains of PGPR at an early stage of development can improve biomass production through direct effects on root and shoot growth. PGPR on vegetables have may result in multiple effects as seen in the enhancement of seed germination, stand health, plant vigor, nutrients content of plant tissues, early bloom and chlorophyll content [45], [46]. PGPR influenced the growth, yield, and increase supply with different nutrients, such as nitrogen, phosphorus, potassium, sulphur, iron and copper, produce plant hormones, enhance other beneficial bacteria or fungi [47].

The increased celery yield might be due to improved media condition which promotes faster decomposed and release of nutrients [48]. When, the decrease in yield might be due to the large volume of straw in which little water was retained, resulting in slower decomposed of the straw and release of nutrient needed for celery plants.

5. Conclusion

It's concluded from illustrated and discussed results that, the old rice straw, 6 months is valid and suitable substrate for growing celery plants and support it to produce its optimum crop yield. In addition, 6 months old rice straw was the best in saving water as well as nutrients depending on the best water use efficiency throughout all tested treatments in this investigation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest is exist.

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