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Efficiency of Azolla and Biochar Application on Rice (*Oryza sativa* L.) Productivity in Salt-Affected Soil

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A field experiment was conducted during two successive summer seasons of 2018 and 2019 to investigate the effect of biochar application rate and Azolla application time on rice (*Oryza sativa L.*) plant productivity under salt affected soils. The obtained data show significant increases of straw and grains yield as well as biological yield (Mgfed^{-1}) as a result of Azolla and biochar application. The treatment of 10 Mg biochar fed^{-1} and Azolla at rate of 180 kgfed^{-1} in two equal doses at 0 and 35 days of transplanting was associated with high yields of straw and grains. Nutrients content (%) and uptake (kgfed^{-1}) as well as the relative changes of their uptake by either straw or grains were increased as a result of individual and combined applications of biochar and Azolla. With the same treatment of biochar and Azolla N, P and K content (%) and uptake (kg fed^{-1}) in grains were higher than those found in straw. There is a wide variation in straw and grains content of N, P and K, in response to the studied treatments. Also, in both straw and grains under different fertilization treatments, the content of the determined nutrients takes the order K> N> P. These findings concluded that, reducing of salt stress and increasing productivity of salt affected soils may be achieved through biochar and Azolla application.

Key words: Azolla, Biochar, Rice production, Salt-affected soil.

Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops for the majority of world population. In Egypt, rice in the second most important food crop next to wheat. Its cultivation area reached about 1.3 million feddan in 2016-2017 season, mainly in the north Delta (CAMPS, 2019). Soils of north Delta are characterized by high salinity. Therefore, beside its importance as a staple food crop, rice is cultivated as a reclaiming crop for such saline and sodic soils (Zayed et al., 2017). Therefore, beside its importance as a staple food crop, rice is cultivated as a reclaiming crop for such saline and sodic soils (Zayed *e*t al., 2017). Salinity is one of the most important environmental stresses that negatively affect soil productivity. Soil salinity results in impairment of plant growth and development through water stress, toxicity of ions such as Na^+ and Cl^-, nutritional imbalances and oxidative stress (Isayenkov, 2012 and Isayenkov and Maathuis, 2019).

Biochar is defined as carbon aceous solid material obtained from thermal decomposition plant-derived biomass in a partial or total absence of oxygen, generally produces for intended application as soil amendment (Mukherjee et al., 2014 and Sohi et al., 2010). Biochar decomposition rate is very slow, and its addition to soils is an effective way for sequestering carbon to mitigate the negative effect of increasing CO_2 concentration in the atmosphere (Sohi, 2013). Several studies including incubation, pot and field experiments showed that biochar application had beneficial effects on soil physical and chemical properties (Suliman et al., 2017 and Mohamed and Hammam, 2019) and plant growth and productivity (Zhang et al., 2012 and Bassouny and Abbas, 2019). In contrast to non-salt-affected soils, few studies have been conducted to investigate the effect of biochar application on salt affected soils. Biochar application to salt-

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affected soils found to increase organic carbon, nutrient content and cation exchange capacity and improve soil physical conditions (Munera-Echeverri et al., 2018 and Zheng et al., 2018). Hammer et al. (2015) reported that biochar application decreased growth depressions caused by salinity, and reduced soil salinity and Na uptake by plants under salinity stress, possibly due to ion adsorption to biochar surfaces.

Nitrogenous fertilizers application has become inevitable to any growing crop to achieve high yield, since almost all agricultural soils respond to their application. Continuous application of mineral fertilizers adversely affect soil organic carbon reserves, soil quality and environmental safety (Subedi and Shrestha, 2015). Integrated use of bio-, organic and mineral fertilizers acts as a key role in crop production in a sustainable way that can achieve higher yield and maintain soil health. Incorporation of bio- and organic fertilizers enhanced physical and chemical properties of salt-affected soil, compensated the deficiency of essential nutrients and increased its productivity of crops (Mousa, 2017, Saied et al., 2017 and Hammouda et al., 2019).

Azolla is a free-floating fresh water efficient Nitrogen fixer. Azolla fix atmospheric nitrogen by forming a symbiotic association with the cyanobacterium *Anabaena azollae*, which is present in the cavity of dorsal lobe of its leaf (Bhuvaneshwari and Singh, 2015). Azolla can save as much as half of the nitrogen requirements of rice crop. Kannaiyan (1993) reported that Azolla can add 40–60 kg N ha^{-1} per rice crop, which is mostly derived from air. Using N 15 tracer elucidated that 33% of the N fixed by Azolla can be assimilated by rice plants within 60 days. Besides, Azolla has several beneficial effects such as, increasing soil organic matter, improving soil physical and chemical properties, suppressing weed growth and mosquito proliferation and minimizing Ammonia volatilization (Pabby et al., 2004 and Awodun, 2008). Kassem and Abd El-Aal (2016) found that using Azolla and compost enhanced fennel growth as well as fruit and essential oil yield and its composition. Asghar et al. (2018) concluded that, application of Azolla reduced the soil EC and soil pH, provided nitrogen, and promoted the rice growth up to certain salinity level.

This field experiment was carried out to study the effect of biochar application at different rates as well as Azolla application at different growth periods on salt affected soil productivity of rice plants and its content of essential nutrients.

Materials and Methods

A field experiment was conducted in a private farm at El-Rwda village, El-Senbellawein, Dakahlia Governorate, Egypt (30° 54′ 21″ N, 31° 24′ 37″ E) during two successive summer seasons of 2018 and 2019 to evaluate the individual and combined applications of biochar (B) and Azolla (A) as organic and bio-fertilizer on rice plants (*Oryza sativa*, Sakha 104 cv)productivity and nutrients content under salt affected soil conditions. The studied treatments were laid out in completely randomized split plot design with three replicates.

Soil sampling and analysis

Before transplanting of rice plants seedlings, surface soil samples (020- cm) of the studied soil were taken from different seven sites, good mixed, air-dried, ground, sieved through a 2 mm sieve and analyzed for some physical and chemical properties as well as its content of available essential plant nutrients as described by Cottenie et al. (1982), Page et al. (1982) and Klute (1986). The obtained data are recorded in Table 1.

Biochar "B"

The used biochar in this study as a soil organic amendment was prepared from sugar cane bagasse through pyrolysis technique at 450˚C, The chemical composition of produced biochar as well as its content of essential plant nutrients were carried out according to Page et al. (1982). The obtained data are listed in Table 2.

Azolla"A"

The microbial inoculants of *Azolla pinnata* was kindly provided by Agricultural Microbiology Research Department, Soil, Water and Environment Research Institute (SWERI), Agriculture Research Center (ARC), Giza, Egypt. Cyano bacteria, *Anabaena oryzaeand Nostoc muscorum,* were added to azolla inoculant as activators to increase its efficiency as proposed earlier by Yanni (1992). Data in Table 2 show the main chemical compounds of the used azolla which carried according to the methods described by El-Shahat (1988) and El-Berashi (2008).

Field experiment

This field experiment was carried out on 756 m^2 at El-Senbellawein, Dakahlia Governorate, where this area was divided into 36 experimental units with 21 m^2 (3×7 m) area for each experimental unit (plot). Before transplanting of rice plants (Oryza sativa, Sakha 104 cv) seedlings, all farming processes and soil preparation were carried

TABLE 1. Physical and chemical properties and the content of available macronutrients of the studied soils

a. Physical properties

Particles size distribution (%)			
Sand	Silt	Clay	Textural class
16.3	27.2	56.5	clay

b. Chemical properties

Organic matter g kg $^{-1}$	CEC (cmole kg $^{-1}$)	pH (1:2.5) soil:water suspension	EC (dS m $^{-1}$) Saturated soil past	ESP (%)	Soluble ions (mmol$_c$ l^{-1}) soil paste ext.							
					Cation				Anion			
					Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
6.9	42.3	8.49	15.22	21.91	31.1	34.73	4.58	81.8	0.0	25.15	90.63	36.43

c. Available nutrient contents (mg kg^{-1})

N	P	K
35.4	9.5	460.4

TABLE 2. Chemical composition of the used biochar and azolla

Biochar		Azolla	
Properties and units	Values	Properties and unit	Value
EC dS/m (1:10 extract)	1.8	Ash content (g Kg-^{1})	105
pH (1:5 susp)	8.4	Crude fat (g Kg-^{1})	30
Bray 1 phosphorus mg/kg	67	Crude protein (g Kg-^{1})	265
Exchangeable cations (cmol/kg)		Soluble sugars (g Kg-^{1})	35
Al	0.03	Starch (g Kg-^{1})	68.3
Ca	2.1	Chlorophyll-a (Ch-a) (g Kg^{-1})	5
K	0.94	N (g Kg^{-1})	40
Mg	0.25	P (g Kg^{-1})	9
Na	0.25	K (g Kg^{-1})	25
CEC Cmol/kg	3.5	Ca (g Kg^{-1})	7
Bray 1 phosphorus mg/kg	67	Mg (g Kg^{-1})	6
KCl extractable ammonium-N mg/kg	2.2	Fe (g Kg^{-1})	7.5
KCl extractable nitrate-N mg/kg	0.2	Mn (g Kg^{-1})	1.4
Total nitrogen %	1.1	OM (g Kg^{-1})	845
Total potassium %	0.25		
Total phosphorus %	0.22		
Total carbon %	65		

according to the recommendations of Agriculture and Soil Reclamation Ministry of Egypt. These plots (36 plot) were divided into three main groups (12 plot/main group) representing the application rate of biochar, *i.e.* 0, 5 and 10 Mg.fed^{-1}, where these treatments were carried out before transplanting with soil preparation. Seedlings transplanting was done with plant spacing of 20×20 cm. The plots of each main group were divided into four sub groups (3 plots/ sub group) representing the treatments of azolla, *i.e.* control (no application), one, two and three doses. Azolla was added in different doses at rate of 180 kg fed^{-1} as a recommended rate recognized by Agricultural Microbiology Research department, Soil, Water and Environment Research Institute, Agricultural Research Center. One dose (180 kgfed^{-1}) was carried out at transplanting, two doses (90 kg fed^{-1}/dose) were carried out at transplanting and at 35 days of the first and the three equal doses treatment (60 kg fed^{-}1/dose) was carried out at transplanting and after 35 and 70 days of the first one. Each treatment was carried in three replicates. The studied treatments and its distribution within the experimental units may be cleared as listed in Table 3. This study was carried out under flooding irrigation system. Irrigation process was carried out according to needing for irrigation. Also, recommended doses of N (100 kg fed^{-1}), P (40 kg fed^{-1}) and K (100 kg fed^{-1}) were added. Phosphorus fertilizer was added before transplanting with soil preparation as ordinary super phosphate (15.5 % P_2O_5), while N and K fertilizers were added on two equal doses at 20 and 50 days of transplanting as ammonium sulphate (20.6 % N) and potassium sulphate (50 % K_2O), respectively. At maturity stage, plants of one m^2 of each replicate were harvested 5 cm above soil surface, air-dried and grains were separated from straw and weighed separately. Both straw and grains yields as Mg/fed were calculated. Harvest index of rice plants was calculated with all studied treatments using the following equation:

$$\text{Harvest index(HI)} = \frac{\text{Grain yeild (Mg/fed)}}{\text{Straw yeild (Mg/fed)+Grains yeild (Mg/fed)}} \times 100$$

(Hay, 1995**)**

A portion of each air-dried plant sample (straw and grains) was taken, oven-dried at 70˚C for 48 hrs., weighed to determine the moisture content (%), ground and kept to determine its content of N, P and K. A 0.2 g of each oven-dried and ground plants sample was taken and digested in 5 ml of H_2SO_4 + $HClO_4$ mixture at mixed ratio 3:1 on sandy plate at 250 ̊C until clear digest was obtained (Chapman and Pratt, 1461). The clear digested was diluted up to 50 ml using distilled water. Using the methods described by Cottenie et al. (1982), digests contents of N, P and K were determined. The obtained data of both straw and grains yields of rice plants and their content of N, P and K were statically analyzed according toSnedecor and Cochran (1982) using CostatStatistical Software (Costat 6.311, Copyright (C) 1998-2005).

Results and Discussion

Straw and grain yields of rice plants

The presented data in Table 3 show the effect of biochar application rate, *i.e.* 0, 5 and 10 $Mgfed^{-1}$ and application time of 180 kg Azolla fed^{-1} at growth time of 0, 35 and 70 days of transplanting in one, two and three doses. These data show significant increases of straw and grains yield as well as biological yield ($Mgfed^{-1}$) as a result of individual and combined applications of biochar and Azolla. For example, straw yield of rice plants was 3.11 $Mgfed^{-1}$ in the control treatment (without any applications of biochar and azolla) which increased to 3.97 Mg fed^{-1} with180 kg Azolla alone in three doses recording RC value of 27.65% and to 4.35 Mg fed^{-1} with individual application of biochar at 10 Mg fed^{-1} recording RC value of 39.87 %. Also, grain yield was 3.65 Mg fed^{-1} in the treatment without any applications of biochar and Azolla which increased to 5.41 Mg fed^{-1} with 180 kg Azolla alone in three doses recording RC value of 45.75% and to 4.85 Mg fed^{-1} with individual application of biochar at 10 Mg fed^{-1} recording RC value of 32.88%. The highest yields of both straw and grains were associated the combined application of Azolla and biochar. Therefore, the RC (%) value of both straw and grains were positive (Table 3). The treatment of 10 Mg biochar fed^{-1} and Azolla at rate of 180 $kgfed^{-1}$ in two equal doses was associated with high yields of straw and grains. For example, biological yield of rice plants increased from 6.76 Mg fed^{-1} in the control treatment (zero application of B and A) to 13.80 Mg fed^{-1} in the treatment of 10 Mg biochar fed^{-1} in combination with 180 kg Azolla fed^{-1} in two equal doses recording RC value of 104.14%. In addition, the mean yield of grains increased from 4.85 to 5.19 and 6.99 $Mgfed^{-1}$ with RC values of 6.24 and 43.04 % with combined application of Azollaat rate of 180 kg/fed in different doses and biochar at application rate of 5 and 10 $Mgfed^{-1}$, respectively. These increases resulted from the impressive effect of biochar on soil physical and chemical properties as well as its effect on available macro and micro nutrients as pointed out before that by El Khamisy (2017) and Mahmoud (2017). Before that, many researchers explained the improveing effect of biochar application on soil properties and productivity. For example, Carvalho et al. (2013) reported that, wood biochar application to clay soil at rate of 0, 8, 16, 32 Mg ha^{-1} led to increase in soil K, Ca, Mg, pH, CEC and nitrate and consequently affected N dynamics. Clough et al. (2016) found that biochar application at rate of 0.6 g kg^{-1} reduced loss of NO_3 and NH_4 from soil. Also, Widowati et al. (2014) studied the effect of biochar application at rate of 0, 15, 30 and 45 Mg ha^{-1} to maize plants in clay loam soil and they found that the lowest K and nitrate leaching was associated with the treatment of 45 Mg ha^{-1}. In another study, Satriawan and Handayanto (2015) reported that, biochar application tended to increase soil Exchangeable Ca, CEC, available essential nutrients such as K, Mg and Mo and total P. Amer (2016) found that application of 2 Mg biochar to clay soil, North Nile Delta, improved soil chemical properties, *i.e.* EC, pH, ESP and CEC and increased N, P and K availability. Dume et al. (2016) found that increasing application rate of biochar to clay loam soil up to 15 Mg ha^{-1} increased CEC, organic matter, total N, exchangeable cations and available P of soil.

In this study, the enhanced effect of Azolla on rice plant growth have wide variations according to its application time and number of doses (Table 4). The highest straw yield was found with the plants fertilized by Azolla in two equal doses at 0 and 35 days of transplanting followed by those found in the plants received Azolla in three doses (at 0, 35 and 70 days of transplanting). Similar findings were observed with grains and biological yields as shown in their relative changes presented in Table 4. For example, with zero application of biochar, biological yields of rice plants were 9.28, 9.54 and 9.38 Mg fed^{-1} with Azolla application in one, two and three equal doses, respectively.The increase in rice yield under saline soil condition as a result of Azolla application may be due to increasing available nitrogen via atmospheric N fixation as well as its role in improving soil chemical and physical properties (Asghar et al., 2018). Helmi (2018) found that, Azolla application to heavy clay saline soil resulted in a significant increases of sugar beet (*Beta vulgaris* L.) yield, where he reviewed these increases to the increase in soil biological activity, total microbial biomass and dehydrogenase activity as a result of Azolla application and also to high content of N and other nutrients. More increases of straw and grain yields of rice plants were found in the combined applications of biochar at 10 Mgfed^{-1} and Azolla at 180 kgfed^{-1} added in two equal doses (Table 4). These results are similar to those obtained by Andreeilee et al. (2015) and Lakitan et al. (2018). These findings mean that, biochar applications increased the efficiency of bio-fertilization in Azolla form. This enhancement effect resulted from the improve effect of biochar on soil biological properties. For example, Shenbagavalli and Mahimairaja found that, soil organic carbon and microbial biomass carbon were markedly increased with increased rate of added biochar. Biochar application found to increase microbial biomass due to presence of labile carbon fraction in un-pyrolized feedstock (Luo et al., 2013). Amini (2015) reported that, application of biochar improved soil microbial biomass and cumulative CO_2. Azeem et al. (2016) found that, biochar application to sandy loam soil significantly increased microbial biomass carbon, dehydrogenase activity and nitrogen.

TABLE 3. Distribution of the studied treatments (Biochar and Azolla application) within the experimental plots

Main plots (Biochar application Mg fed^{-1})	Sub plots (Azolla application doses)	Treatment description
0	0	Without any applications of biochar or Azolla.
	1	Azolla only in single at application rate 180 kg fed^{-1} at transplanting.
	2	Azolla only in two equal doses at application rate 90 kg fed^{-1} at transplanting and 35 days after.
	3	Azolla only in three equal doses at application rate 60 kg fed^{-1} at transplanting and after 35 and 70 days
5	0	Biochar only at application rate of 5 Mg fed^{-1}.
	1	Biochar at application rate of 5 Mg fed^{-1} with Azolla in single dose at application rate 180 kg fed^{-1} at transplanting.
	2	Biochar at application rate of 5 Mg fed^{-1} with Azolla in two equal doses at application rate 90 kg fed^{-1} at transplanting and after 35 days.
	3	Biochar at application rate of 5 Mg fed^{-1} with Azolla only in three equal doses at application rate 60 kg fed^{-1} at transplanting and after 35 and 70 days.
10	0	Biochar only at application rate of 10 Mg fed^{-1}.
	1	Biochar at application rate of 10 Mg fed^{-1} with Azolla in single dose at application rate 180 kg fed^{-1} at transplanting.
	2	Biochar at application rate of 10 Mg fed^{-1} with Azolla in two equal doses at application rate 90 kg fed^{-1} at transplanting and after 35 days.
	3	Biochar at application rate of 10 Mg fed^{-1} with Azolla only in three equal doses at application rate 60 kg fed^{-1} at transplanting and after 35 and 70 days.

TABLE 4. Effect of application rate of biochar (B) and azolla (A) application time on straw and grains yields (Mg fed^{-1}) of rice plants as well as its relative changes "RC" (%)

Treatments		Straw yield		Grain yield		Biological yield	
Added biochar (Mg fed^{-1})	Added azolla (doses)	Mg fed^{-1}	RC, %	Mg fed^{-1}	RC, %	Mg fed^{-1}	RC, %
0	0	3.11 j	-	3.65 j	-	6.76 k	-
	1	4.12 g	32.48	5.16 g	41.37	9.28 h	37.28
	2	4.22 f	35.69	5.32 f	45.75	9.54 f	41.12
	3	3.97 h	27.65	5.41 e	48.22	9.38 g	38.76
5	0	3.25 i	4.50	3.82 i	4.66	7.07 j	4.59
	1	4.31 e	38.59	5.32 f	45.75	9.63 e	42.46
	2	4.57 d	46.95	5.82d	59.45	10.30 d	53.70
	3	4.58 d	47.27	5.80 d	58.90	10.38 d	53.55
10	0	4.35 e	39.87	4.85 h	32.88	9.20 i	36.09
	1	5.62 b	80.71	7.50 c	105.48	13.12 b	94.08
	2	5.88 a	89.07	7.92 a	116.99	13.80 a	104.14
	3	5.32 c	71.06	7.68 b	110.41	13.00 c	92.31
Biochar	0	3.85 c	-	4.85 c	-	8.74 c	-
	5	4.18 b	8.37	5.19 b	6.24	9.37 b	7.18
	10	5.29 a	37.29	6.99 a	43.04	12.28 a	40.50
Azola	0	3.57 d	-	4.11 d	-	7.68 d	-
	1	4.68 b	31.43	5.99 c	45.09	10.68 c	38.70
	2	4.89 a	37.16	6.35 a	53.80	11.24 a	46.03
	3	4.62 c	30.29	6.30 b	52.80	10.92 b	42.29

In addition, Fig.1 show harvest index (HI) of rice plants grown in clay saline soil in relation with the experimental treatments of Azolla and biochar individually and in combination. Harvest index "HI" was calculated by equation of Hay (1995). The obtained results show the high importance of the studied treatments on rice plant growth. Also, the obtained data show that, the studied treatments of biochar and Azolla have a more increase of grains yields of rice plants compared with these found in straw yields. These findings show the high importance of biochar and Azollaapplications on the increase of rice economic yields. With all applications of biochar and Azollaalone and in together, grains yield was higher than that found with straw yield. In this respect, as well as under salt-affected soils, findings are in agreement with those obtained by Amer (2016) for some field crops treated with biochar and by Helmi (2018) with wheat plants treated by Azolla.

Rice plants content of nutrients

Both concentration (%) and uptake (kgfed^{-1}) of N, P and K by straw and grains of rice plants fertilized by biochar at rates of 0, 5 and 10 Mgfed^{-1} alone and in combination with 180 kg Azolla fed^{-1} applied in one, two and three equal doses at different growth times were studied and the found values are recorded in Tables 5 and 6. Nutrients *i.e.* N, P and K content (%) and uptake (kg fed^{-1}) well as the relative changes of their uptake were

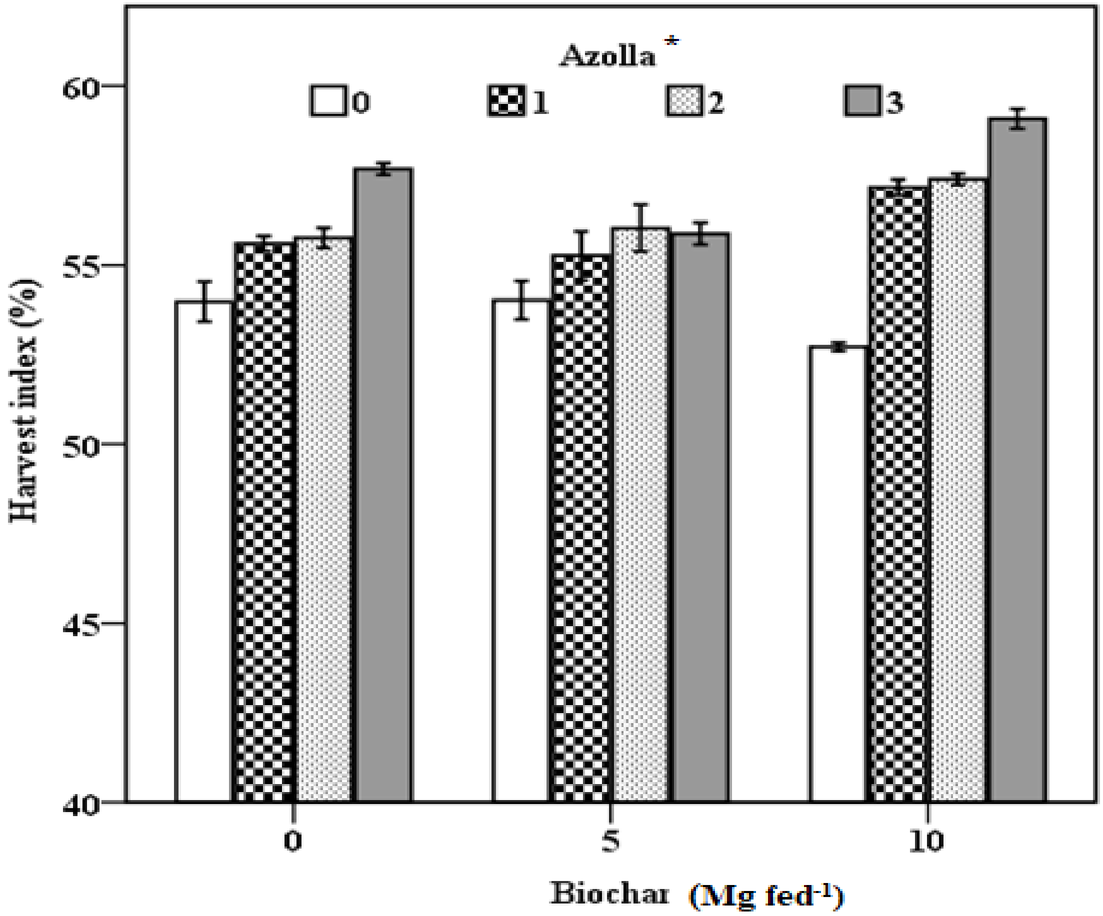

Fig. 1. Effect of application rate of biochar (B) and azolla (A) application time on harvest index "HI" (%) of rice plants
*Number of added doses of Azolla

increased as a result of individual and combined applications of biochar and Azolla. With the same treatment of biochar and Azolla N, P and K contents (% and kgfed^{-1}) in the grains were higher than those found in straw, where the rate of these increases varied widely from treatment to another. The rate of these variations may be cleared from the calculated values RC (%) of N, P and K uptake by either of straw or grains. Also, in both straw and grains as well as with the studied fertilization treatments, the content of the determined nutrients takes the order K> N> P.

The found increases of N, P and K content in the rice plants (straw and grains) as a result of biochar and Azolla application means that, under clay and saline soils application of the tested organic (biochar) and bio (Azolla) fertilizer are very important and have a high efficiency. These conclusions are similar with these obtained by Amer (2016), El Khamisy (2017), Mahmoud (2017) and Helmi (2018). Also, before that, Tantawy et al. (2011) pointed that straw and grains yields of rice plants grow in clay soil as well as their content of N, P and K were increased significantly as a result of bio fertilizers application.

Recently, Elshahri (2020) found a significant increase of N, P and K uptake by sugar beet plants grown on clay soil of Menoufia Governorate, Egypt as a result of biochar application up to rate of 2%. Such increase of plant content of N, P and K were found before that by other researchers, where they attributed these increase to the effect of biochar application on the soil content of N, P and K (Amer, 2016). In addition, biochar application resulted in reduced NH_4-N, NO_3-N and K loss from soil by leaching (Clough et al., 2016 and Widowati et al., 2014). Also, Dume et al. (2016) pointed out that, biochar applications increased soil content of dissolved organic matter and resulted in more availability of essential nutrients. Similar increases of rice plants (straw

TABLE 5. Straw of rice plants concentration (%) and uptake of N, P and K (kg fed^{-1}) and its relative changes "RC" affected by application rates of biochar and application time of azolla under salt affected soils conditions

Treatments		N			P			K		
Added biochar (Mg fed^{-1})	Added azolla (doses)	Conc. %	Uptake kg fed^{-1}	RC %	Conc. %	Uptake kg fed^{-1}	RC %	Conc. %	Uptake kg fed^{-1}	RC %
0	0	0.38 h	11.84 g	-	0.25 i	7.79 i	-	1.39 g	43.24 h	-
	1	0.45 fg	18.56 f	18.42	0.32 gh	13.20 g	28.00	1.50 fg	61.93 f	7.91
	2	0.51 cde	21.56 de	34.21	0.35 f	14.79 fg	40.00	1.65 de	69.74 e	18.71
	3	0.54 c	21.40 e	42.11	0.41 e	16.30 f	64.00	1.71 cd	67.91 e	23.02
5	0	0.40 gh	12.98 g	54.74	0.30 h	9.76 h	25.32	1.50 fg	48.82 g	12.77
	1	0.48 def	20.73 ef	75.04	0.35 f	15.11 f	93.96	1.56 ef	67.29 ef	55.54
	2	0.52 cd	23.82 cd	101.02	0.41 e	18.76 e	140.87	1.74 cd	79.67 cd	83.95
	3	0.54 c	24.76 c	109.22	0.46 d	21.09 d	170.82	1.82 abc	83.39 c	92.83
10	0	0.46 ef	20.06 ef	69.29	0.34 fg	14.76 fg	90.10	1.78 bc	77.53 d	79.11
	1	0.55 c	30.96 b	161.51	0.52 c	29.18 c	275.58	1.81 abc	101.80 b	135.30
	2	0.61 b	35.91 a	203.47	0.59 b	34.72 a	345.89	1.91 a	112.27 a	151.63
	3	0.67 a	35.67 a	201.52	0.62 a	33.01 b	323.91	1.89 ab	100.48 b	132.59
Biochar	0	0.47 c	18.12 d	-	0.33 c	12.82 c	-	1.56 c	60.23 c	-
	5	0.49 b	20.26 c	11.81	0.38 b	16.16 b	26.07	1.66 b	69.72 b	15.75
	10	0.57 a	30.61 b	68.93	0.52 a	27.92 a	117.78	1.83 a	97.12 a	61.25
Azola	0	0.41 d	16.71 a	-	0.30 d	10.77 c	-	1.56 d	56.47 d	-
	1	0.49 c	23.38 c	39.92	0.40 c	19.16 b	77.93	1.62 c	76.92 c	36.21
	2	0.55 b	27.05 b	61.88	0.45 b	22.73 a	111.08	1.75 a	85.98 a	52.25
	3	0.58 a	27.27 a	63.20	0.50 a	23.44 a	117.67	1.81 b	83.93 b	48.63

and grains) content of N, P and K were found as a result of bio-fertilizer applications under clay and saline soil conditions. Abd El Salam (2019) and El-Noamany (2020) found a significant increase of N, P and K uptake by straw and seeds of peanut plants as a result of bio fertilization in different sources under some soil conditions of Egypt. Increased nutrients uptake may beattributed to the effect of the usedbio-fertilizers on soil biomass, biological activity, nutrients availability and improve in most soil properties, which have a positive and increase effect on plant growth and productivity.

Data in Tables 5 and 6 show that, with all Azollaand biochar applications individually and in combination, the highest N, P and K content (%) and uptake (kgfed^{-1}) as well as RC (%) of these nutrients uptake by straw and grains of rice plants were found in the plants grown on the soil received Azollain two equal doses (90 kgfed^{-1}/dose) at transplanting and after 35 days of the first one in combination with 10 Mg biochar fed^{-1} followed by those found in the plants received Azolla applications in three equal doses at 0, 35 and 70 days of transplanting with the same rate of added biochar. These findings were more cleared from RC (%) values of these nutrients uptake.

Conclusions

In conclusion , the results obtained underscored the hypnosis of this study that the use of Azolla and biochar increased the productivity of rice under saline soil conditions. Also, the application of Azolla to rice fields in separate doses will ultimately sustainably increase rice productivity. It may be more effective for rice production if it is applied especially under salt-affected soil conditions, in combination with biochar. That means the application of Azolla in combination with biochar reduces the harmful effects of salt stress, as well as to decrease the used rate of added mineral fertilizers, where these additives considered as good sources for many essential nutrients.

TABLE 6. Grains of rice plants concentration (%) and uptake of N, P and K (kg fed-1) and its relative changes "RC" affected by application rates of biochar and application time of azolla under salt affected soils conditions

Treatments		N			P			K		
Added biochar (Mg fed^{-1})	Added azolla (doses)	Conc. %	Uptake kg fed^{-1}	RC %	Conc. %	Uptake kg fed^{-1}	RC %	Conc. %	Uptake kg fed^{-1}	RC %
0	0	0.40 j	14.63 k	0.00	0.27 h	9.90 i	0.00	1.40 j	51.17 k	0.00
	1	0.51 i	26.34 i	80.25	0.33 g	16.98 h	72.79	1.55 h	80.07 h	56.52
	2	0.70 f	37.28 g	155.07	0.40 f	21.31 fg	115.93	1.68 f	89.48 g	74.90
	3	0.76 e	41.14 f	181.62	0.43 ef	23.29 f	136.05	1.71 e	92.59 f	81.04
5	0	0.50 i	19.17 j	30.82	0.40 f	15.31 h	55.05	1.50 i	57.38 j	12.13
	1	0.67 g	35.66 h	144.14	0.54 c	28.71 de	191.51	1.67 f	88.88 g	73.86
	2	0.78 d	45.42 e	210.93	0.50 d	29.11 d	195.28	1.84 b	107.12 d	109.57
	3	0.88 b	51.08 d	249.59	0.46 e	26.72 e	170.73	1.78 c	103.31 e	102.04
10	0	0.53 h	25.74 i	76.06	0.40 f	19.43 g	96.85	1.57 g	76.21 i	49.01
	1	0.75 e	56.30 c	285.27	0.51 cd	38.29 c	288.13	1.75 d	131.30 c	156.85
	2	0.85 c	67.33 b	361.10	0.59 b	46.76 b	374.16	1.90 a	150.54 a	194.48
	3	0.96 a	73.77 a	404.99	0.65 a	49.95 a	406.54	1.84 b	141.36 b	176.54
Biochar	0	0.59 c	29.82 c	-	0.36 c	17.86 c	-	1.59 c	78.24 c	-
	5	0.71 b	37.80 b	26.74	0.48 b	24.95 b	39.68	1.70 b	89.12 b	13.90
	10	0.77 a	55.75 a	86.96	0.54 a	38.57 a	115.98	1.77 a	124.80 a	59.51
Azola	0	0.48 d	19.80 d	-	0.36 c	14.85 c	-	0.48 a	19.80 d	-
	1	0.64 c	39.40 c	99.01	0.46 b	28.00 b	88.57	0.64 c	39.40 c	99.01
	2	0.78 b	49.99 b	152.45	0.50 a	32.37 a	117.98	0.78 a	49.99 a	152.45
	3	0.87 a	55.29 a	179.27	0.51 a	33.29 a	124.16	0.87 b	55.29 b	179.27

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كفاءة استخدام الأزولا و الفحم الحيوي على انتاجية الأرز في الأرض المتأثرة بالاملاح

أجريت تجربة حقلية بمزرعة خاصة تحت ظروف الأرض المتأثرة بالأملاح بقرية الروضة بمنطقة السنبلاوين – محافظة الدقهلية (30° 54□ 21□ شمالا و 31° 24□ 37□ شرقا) خلالموسمي صيف 2018 و 2019 وذلك لدراسة تأثير اضافات الفحم الحيوى منفردا وفى صورة اضافات مشتركة مع الأزولا على انتاجية محصول الأرز بالاضافة الى محتواه من بعض المغذيات. حيث أضيف الفحم الحيوى عند معدلات 0, 5 , 10 طن /فدان . بينما أضيفت الأزولا عند معدلى صفر , 180 كجم /فدان عند ثلاث فترات نمو وكذلك على جرعات مختلفة (عند الشتل, وبعد 35 يوم , وبعد 70 يوم) من الزراعة . وقد تم توزيع معاملات الدراسة على الوحدات التجريبية فى نظام قطع منشقة فى ثلاث مكررات. وهذا وضحت نتائج الدراسة وجود زيادة معنوية فى محصول القش والحبوب وكذلك المحصول البيولوجى نتيجة لاضافات الفحم الحيوي والأزولا. ولقد صاحب المعاملات المشتركة للفحم الحيوى والأزولا زيادة فى محصولى القش والحبوب مقارنة بالاضافات المنفردة لهذا كانت جميع قيم التغير النسبي لمحصولى القش و الحبوب وعلاقتها بمعاملات الدراسة موجبة وكذلك أوضحت نتائج الدراسة أن اضافة الأزولا على دفعتين مساويتين صاحبها زيادة فى محصول القش والحبوب مقارنة بنتائج المعاملتين الأخرتين منفردة أو مجمعة مع الفحم الحيوى وبذلك كانت أعلى قيم محصول الأرز موجودة فى النباتات المنزرعة فى الأرض المعاملة بالفحم الحيوى عند معدل اضافة 10 طن/فدان واضافة الازولا بمعدل 180 كجم/فدان على دفعتيين متساويتين عند الشتل وبعد 35 يوم من الدفعة الأولى وكذلك فقد أوضحت نتائج الدراسة وجود زيادة معنوية فى محتوى(٪ , كجم/فدان) القش والحبوب من النيتروجين والفوسفور والبوتاسيوم مع الاضافات المختلفة للفحم الحيوى والأزولا. و مع نفس معاملة الدراسة كان محتوى الحبوب من عناصر الدراسة أعلى من ذلك فى القش مع وجود اختلافات واضحة فى هذا المحتوى طبقا لمعاملة الدراسة كما وجد أنه فى كل من القش والحبوب أمكن ترتيب المغذيات المقدرة طبقا للمحتوى كما يلى البوتاسيوم > النيتروجين > الفوسفور. وتشير نتائج الدراسة إلى إمكانية التغلب على الإجهاد الملحى وكذلك زيادة إنتاجية الأراضى المتأثرة بالأملاح عن طريق إضافة الفحم الحيوي مع الأزولا.