International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.4, pp 1610-1617, 2015

Sustainable production of wheat in new reclaimed sandy soil

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Abstract: Two field experiments were carried out at the Agricultural Production and Research Station, National Research Centre, Nubaria Province, Behaira Governorate, Egypt, during the two successive winter seasons of 2012/2013 and 2013/2014 to study the effect of addition of charcoal and biofertilizer with Azolla or Mycorrhiza on growth, yield and its components, some chemical constituents and uptake of N, P, K and crude protein. The results indicated that addition of charcoal increase most growth characters at 100 days after sowing under study as compared with control treatment. Biofertilizer inoculation also produced significant increments in all growth characters with superiority to Mycorrhiza.

The interaction between addition of charcoal and biofertilizer caused a significant effect on plant height(cm), number of spikes/ m^2, dry weight of spikes(g/m^2), blades area (cm^2/m^2), dry weight of blades (g/ m^2), flag leaf area (cm^2) and dry weight of plant (g/m^2) at 100 days after sowing. Yield and yield attributes of wheat plants significantly affected by biofertilizer inoculation with superiority to Mycorrhiza over Azolla. Association of addition of charcoal and biofertilizer led to a significant increase in number of grains/ spike, weight of grains/ spike (g), grain index (g) as well as grain, straw and biological yields (ton/fed.) except harvest index.

Inoculation with Azolla or Mycorrhiza had a significant positive effect on N, P, K and crude protein of wheat grains. The maximum increases N, P, K, crude protein of wheat grains and protein yield/fed were obtained by addition of charcoal and Mycorhiza. Addition of Charcoal had significant effects on N, P and K uptake of wheat grains. The highest increases of N, P and K uptake of wheat grains were obtained by addition of charcoal and inoculation with Mycorrhiza.

Key words: Wheat, addition of charcoal, biofertilizer, yield and yield attributes.

Introduction

Wheat (*Triticum aestivum,* L.) is the most strategic cereal crop in the world as well as in Egypt. Egypt suffers from food shortage problem as result of a huge increment of population and the low level of national income. Therefore, Egypt is considered the biggest importer of wheat in the world. Extensive efforts are continuously paid for increasing its productivity by means of vertical and/or horizontal planting to decrease gap between production and consumption. Increasing cultivation in new reclaimed sandy soils became a vital subject but, these soils are characterized with poor fertility, low water holding capacity, high leaching and alkaline pH.

Charcoal is the dark grey residue consisting of carbon, and any remaining ash, obtained by removing water and other volatile constituents from vegetation substances. It is usually produced by slow pyrolysis at temperatures from ca. 300 to 600 °C [1]. There are some researches that shows charcoal can be used as a possible means to improve soil fertility as well as other ecosystem services and sequester carbon for reduction of carbon mitigation (C) to mitigate climate change[2, 3, 4].

Application of biofertilizer is considered today to limit the use of mineral fertilizers and supports an effective tool for desert development under less polluted environments, decreasing agricultural costs, maximizing crop yield due to providing them with an available nutritive elements and growth promoting substances [5]. Arbuscular Mycorrhizae (A M) play an important role in facilitating carbon translocation from above-ground to underground structures. AM fungi help plants to capture water and nutrients from the soil, and in return, the plant provides the fungus with relatively constant and direct access to carbohydrates[6, 7]. The use of biofertilizer in such soil showed a good means in that concern. Numerous studies have shown a substantial increase in growth and yield of wheat plant in reclaimed sandy soils[7, 8, 9, 10, 11].

The objective of the current work is to study the effect of addition of Charcoal and biofertilizer on growth, yield and yield attributes, chemical constituents and uptake of wheat grains in new reclaimed sandy soil.

Materials and Methods

Two field experiments were carried out at the Agricultural Production and Research Station, National Research Centre, Nubaria Province, Behaira Governorate, Egypt, during the two successive winter seasons of 2012/2013 and 2013/2014 to study the effect of addition of Charcoal and biofertilizer inoculation with Azolla or Mycorrhiza on growth, yield and its components, some chemical constituents and uptake of wheat grains. The surface soil sample (0-30 depth) of the experimental area was subjected to laboratory analysis to determine some of its mechanical and chemical properties according to the method described by [12] in Table (1).

Table (1): Mechanical and chemical analyses of the experimental soil (2012/2013 and 2013/2014 seasons).

Mechanical analysis:	**2012/2013**	**2013/2014**
Sand %	92.3	90.1
Silt %	3.1	4.3
Clay %	4.6	5.6
Chemical analysis:	**2012/2013**	**2013/2014**
$CaCo_3$ %	1.3	1.5
Organic matter %	0.3	0.3
EC. mmhos/cm^2	0.3	0.3
pH	7.4	7.2
Soluble N%	8.0	8.2
Available P (ppm)	3.0	3.4
Available K (ppm)	19.8	20.2

The experimental design was split plots design with four replicates. Charcoal was assigned to the main plots (without charcoal and addition of charcoal (4 tons/fed.)), while biofertilizer inoculation were randomly distributed in the sub plots (Control, Azolla (1L/fed.) or Mycorrhiza (1kg/fed.). Wheat grains were planted on 14th and 16th November in 2012 and 2013 in both seasons, respectively. Irrigation was carried out using sprinkler irrigation system where water was added every 5 days. The normal agronomic practices of growing wheat were practiced till harvest as recommended by wheat Research Dept .A.R.C., Giza.

Samples of one square mater were taken at random from the middle area of each plot from the three replicates to measure plant height cm, number of spikes /m^2, dry weight of spikes g/m^2, blades area cm^2 /m^2, dry weight of blades (g/ m^2), Flag leaf area cm^2 and dry weight of plant (g/m^2) at 100 day from sowing. At harvest time one square meter was taken at random from the middle area of each plot from the three replicates to determine: number of grains/ spike, weight of grains/ spike (g), grain index (g) grain yield (g). In addition, grain, straw, biological yields ton/fed and harvest index were determined from the whole area of experimental units from the other three replication were taken for the yield determined and the converted to yield per feddan and harvest index% = grain yield/biological yield x100. NPK in grains were determined according to the method described by [13]and the grain protein content was calculated by multiplying total nitrogen concentration by 5.75. N, P and K uptake of wheat grains. Statistical analysis was performed according to [14]. Treatments mean were compared by L.S.D. test. Combined analysis was made from the two growing seasons hence the results of two seasons followed similar trend.

Results and Discussion

Growth characters

Data presented in (Table 2) show that, addition of charcoal increase most growth characters i.e. plant height (cm), number of spikes /m^2, dry weight of spikes (g/m^2), blades area (cm^2 /m^2), dry weight of blades (g/ m^2), flag leaf area (cm^2) and dry weight of plant (g/m^2) at 100 day from sowing, but this increase did not reach to significant. This results might be due to the stimulation effect addition of charcoal on improving the physical properties of the soil, increasing soil fertility and increasing the availability of many nutrients element to plant uptake, which in turn on improving the growth of wheat plants. Such pronouncing effect of application of charcoal in increasing growth was recorded by many investigators [15, 16] who reported that the total net growth is increase according to charcoal use.

It is clear also from Table (2), that plant height(cm), number of spikes /m^2, dry weight of spikes (g/m^2), dry weight of blades (g/ m^2), flag leaf area (cm^2) and dry weight of plant (g/m^2) at 100 day from sowing were significantly affected by inoculation with Azolla or Mycorrhiza except blades area(cm^2 /m^2). Inoculation with Mycorrhiza greatly increased most growth characters of wheat plants compared to inoculation with Azolla but there was no significant between inoculation with Azolla or Mycorrhiza on all growth characters. Mycorrhiza increases the surface areas of plant root systems, which facilitate uptake of nutrients and water [17]. Biofertilization is very safe for human, animal and environment to get lower pollution and saving fertilization cost. In addition, their inoculation in soil improves soil biota and minimizes the sole use of chemical fertilizers[18]. Similar results were obtained by[8,10] who revealed that the biotreatments produced significant increments in all growth characters under study.

The interaction between addition of charcoal and biofertilizer caused a significant effect on plant height(cm), number of spikes/ m^2, dry weight of spikes(g/m^2), blades area (cm^2 /m^2), dry weight of blades (g/ m^2), flag leaf area (cm^2) and dry weight of plant (g/m^2) at 100 days after sowing (Table 2).

Addition of charcoal and inoculation with Mycorrhiza recorded the highest values of all growth characters at 100 days after sowing, while the lowest values of these characters were recorded when untreated plant (control). These results are in line with those obtained by [19]. Addition of charcoal enhanced the efficiency of inorganic fertilizer due to decrease in losses of inorganic N.

Table (2) Effect of Addition of charcoal, Inoculation with Azolla or Mycorrhiza and interaction between them on some growth characters of wheat.

Treatments / Characters		Plant height (cm)	Number of spikes /m^2	Dry weight of spikes (g/m^2)	Blades area (cm^2/m^2)	Dry weight of blades (g/m^2)	Flag leaf area (cm^2)	Dry weight of plants (g/m^2)
Charcoal treatment								
Without(Control)		85.97	336.72	405.55	57816.45	307.78	42.29	1022.71
Addition of charcoal		88.73	351.12	420.96	59106.37	316.46	43.46	1051.56
LSD at 5%		NS	NS	NS	NS	NS	NS	NS
Inoculation treatment								
Control		82.93	333.89	397.73	56917.79	300.94	40.12	999.62
Azolla		87.84	340.00	413.50	58464.69	311.12	42.82	1035.74
Mycorrhiza		91.28	357.88	428.53	60001.75	324.30	45.69	1076.04
LSD at 5%		4.89	20.12	21.02	NS	17.65	2.87	51.36
Interaction treatment								
Without	**Control**	81.40	325.12	389.15	56423.21	298.54	39.21	986.22
	Azolla	87.48	338.61	411.82	58225.96	309.85	42.65	1031.51
	Mycorrhiza	89.02	346.43	415.69	58800.18	314.94	45.02	1050.40
Charcoal	**Control**	84.45	342.65	406.32	57412.36	303.35	41.03	1013.02
	Azolla	88.20	341.39	415.19	58703.42	312.39	43.00	1039.97
	Mycorrhiza	93.54	369.32	441.36	61203.32	333.65	46.35	1101.69
LSD at 5%		8.88	35.25	40.02	561.36	31.25	4.23	99.36

2-Yield and yield attributes:-

Data presented in Table (3) show that, addition of charcoal had a significant effect on straw and biological yields (ton/fed.). On the other hand the effect on number of grains/ spike, weight of grains/ spike (g), grain index (g) as well as grain yield (ton/fed.) was not significant. The use of charcoal in agricultural systems may reduce the need for using commercial fertilizers and have positive carbon sequestration effects, which in turn will help our environment and increase crop yields simultaneously. Results are in concert with those obtained by [16]. Furthermore, the improvement of soil water-holding capacity by biochar addition could maintain a better moisture level between irrigation periods, being considered a key factor to obtain good grain yield in wheat [20]. Recently, [21]found that Biochar increased soil porosity and cation exchange capacity, suggesting that it may help to prevent nutrient leaching losses.

The same table also showed that, yield and yield attributes of wheat plants significantly affected by biofertilizer. Inoculation with Mycorrhiza was superior to inoculation with Azolla.The utilization of biofertilizer has several advantages over chemical fertilizer. It is inexpensive, making use of freely available solar energy, atmospheric nitrogen and water. it utilize renewable resource, whereas the production of chemical fertilizer depends on petroleum , a diminishing resources .The applications of biofertilizer in agriculture are suggested as a sustainable way of increasing crop yields and economize their production as well [19]. This increment of yield and yield attributes may be due to the effect of biofertilizer which play important role of assimilation of wheat plants that reflected on enhancing these characters.

Regarding the interaction effect of addition of charcoal and biofertilizer on yield and yield attributes, table (3) show that addition of charcoal and biofertilizer led to a significant increase in number of grains/ spike, weight of grains/ spike (g), grain index (g) as well as grain, straw and biological yields (ton/fed.) except harvest index. This increasing in yield appears because of ability of charcoal for improving soil condition from increasing water holding capacity to increasing number of useful soil microorganisms [22]. At the highest mineral fertilizer rate, addition of biochar led to about 20–30 % increase in grain yield compared with the use of the mineral fertilizer alone[20].

From the previous results, it can be concluded that addition of charcoal combination with biofertilizer may increase availability and uptake of nutrients for wheat plants. These results are in harmony with those obtained by[5] who showed that soil microbial population *viz.* Actinomycetes, Bacteria, Fungi and BGA increased due to the application of organic amendments which further influenced the soil dehydrogenase and phosphatase enzyme activities.

Table (3) Effect of Addition of charcoal, Inoculation with Azolla or Mycorrhiza and interaction between them on yield and yield attributes of wheat.

Characters Treatments		Grain	Straw	Biological	Harvest index	Number of grains /spike	Dry weight of grains /spike (g)	1000-grains weight (g)
		yield (ton/fed.)						
Charcoal treatment								
Without(Control)		1.97	2.47	4.44	44.48	55.02	2.56	44.95
Addition of charcoal		2.08	2.70	4.79	43.48	57.21	2.70	46.48
LSD at 5%		NS	0.15	0.23	NS	NS	NS	NS
Inoculation treatment								
Control		1.77	2.23	4.00	44.23	52.16	2.38	42.99
Azolla		2.07	2.74	4.81	43.06	58.21	2.67	46.66
Mycorrhiza		2.25	2.79	5.04	44.64	57.99	2.85	47.51
LSD at 5%		0.13	0.15	0.23	NS	3.36	0.13	2.77
Interaction treatment								
Without	**Control**	1.72	2.08	3.80	45.26	51.02	2.33	42.32
	Azolla	2.05	2.66	4.71	43.56	58.40	2.61	46.16
	Mycorrhiza	2.15	2.67	4.82	44.61	55.65	2.74	46.36
Charcoal	**Control**	1.81	2.38	4.19	43.20	53.3	2.43	43.65
	Azolla	2.09	2.82	4.91	42.57	58.01	2.73	47.15
	Mycorrhiza	2.35	2.91	5.26	44.68	60.32	2.95	48.65
LSD at 5%		0.21	0.29	0.51	NS	6.02	0.26	4.23

3-N, P, K of wheat and crude protein grains

Data presented in (Table 4) show that, N, P, K and crude protein of wheat grains increased by addition of charcoal. However, this increase was only significantly for the percentage of K in the grains of wheat plant. Addition of charcoal to soil management strategies can enhance wheat production with the environmental benefits of global warming mitigation. This trend could be explained on a basis that the charcoal served to stabilize the organic matter in the soil, increased cation exchange capacity and increased water retention due to its porous structure and high surface area[21]. With respect to response of various studied N, P, K and crude protein of wheat grains to biofetilizer inoculation, Table (4) show that inoculation with Azolla or Mycorrhiza had a significant positive effect on N,P,K and crude protein of wheat grains. Bio-fertilization is very safe for human, animal and environment to get lower pollution and saving fertilization cost[18].

Concerning the effect of interaction between addition of charcoal and biofertilizer on N, P, K and crude protein, data in Table (4) show a significant interaction between addition of charcoal and biofertilizer on N, P, K and crude protein of wheat grains. Generally, the maximum increases N, P, K and crude protein of wheat grains were obtained by addition of charcoal and inoculation with Mycorhiza. Biochar have been mainly related to a greater nutrient retention, minimizing nutrient losses, improvements in soil properties like increase in water-holding capacity, decrease in soil compaction, liming effect leading to immobilization of contaminants or nutrient mobilizations and enhancement in soil biological properties such as more favorable root environment, microbial activities favoring nutrient availability[20]. Increase in N, P, K and crude protein in wheat grain further indicated that their use not only maintain the soil productivity but also improve the grain quality.

Table (4) Effect of Addition of charcoal, Inoculation with Azolla or Mycorrhiza and interaction between them on N, P, and K of wheat, crude protein grains and protein yield/fed.

Treatments	Characters	N%	P%	K%	Crude protein%	Protein yield/fed.
Charcoal treatment						
Without(Control)		2.10	0.40	1.80	13.13	259.97
Addition of charcoal		2.18	0.41	1.96	13.65	285.48
LSD at 5%		NS	NS	0.13	NS	14.65
Inoculation treatment						
Control		2.02	0.37	1.73	12.63	222.94
Azolla		2.19	0.41	1.86	13.66	282.73
Mycorrhiza		2.22	0.45	2.06	13.88	312.50
LSD at 5%		0.18	NS	0.17	1.01	16.36
Interaction treatment						
Without	**Control**	1.98	0.35	1.68	12.38	212.85
	Azolla	2.15	0.40	1.81	13.44	275.47
	Mycorrhiza	2.17	0.45	1.92	13.56	291.59
Charcoal	**Control**	2.06	0.38	1.78	12.88	233.04
	Azolla	2.22	0.41	1.90	13.88	289.99
	Mycorrhiza	2.27	0.44	2.19	14.19	333.41
LSD at 5%		0.27	0.03	0.2	1.22	24.65

4-N, P and K uptake of wheat grains (kg/fed.)

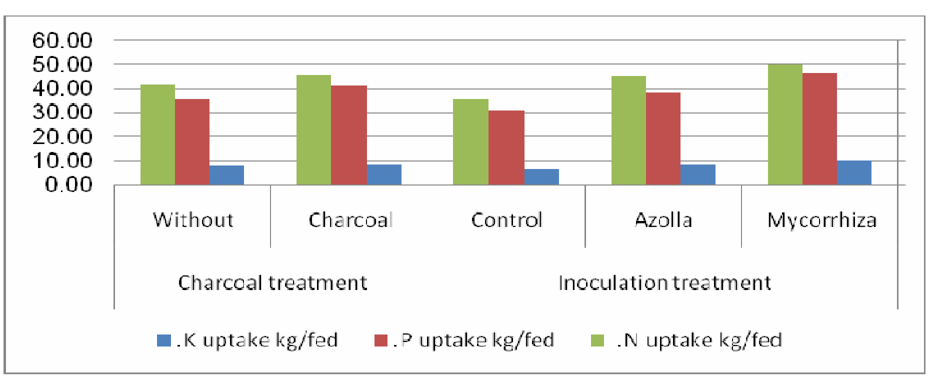

Fig. (1) Effect of Addition of charcoal and inoculation with Azolla or Mycorrhiza on N, P and K uptake of wheat grains

Compared to the control, Addition of charcoal had significant effects on N, P and K uptake of wheat grains (Fig.1). Positive impact of biochar could be due to its nutrient value, supplied either directly by providing nutrients to plants or indirectly by improving soil quality, with consequent improvement in the efficiency of fertilizer use. As a measure of the direct nutrient value of biochar, it is not the total content but, rather, the availability of the nutrient that is an important consideration. Moreover, the indirect nutrient value of biochar is its ability to retain nutrients in the soil and, therefore, to reduce leaching losses, resulting in increased nutrient uptake by plants and higher production[23].These results are in harmony with those obtained [by 1, 24] who found that there was a negative trend in yield and nutrient uptake when N was not supplemented, indicating that even high total N pools in wood-based BC are released too slowly to contribute significantly to plant nutrition.

Inoculation with Azolla or Mycorrhiza significantly increased N, P and K uptake of wheat grains in (Fig. 1). Similar results were obtained by [25] who found that phosphorus uptake in many crops is improved by associations with Arbuscular Mycorrhizal fungi, particularly in low P soils. Biofertilizers improve the general fertility of the soil by increasing the availability to crop of a number of nutrients, by increasing the organic matter in soil and by improving soil structure.

Data presented in (Fig. 2) indicated that the interaction between addition of charcoal and inoculation with Azolla or Mycorrhiza were significant in N, P and K uptake of wheat grains. The highest increases of these characters were obtained by addition of Charcoal and inoculation with Mycorrhiza. Charcoal additions affected microbial biomass and microbial activity, as well as nutrient availability, differences in the magnitude of the microbial response was dependent on the differences in base nutrient availability in the soils studied. However, they noted that the influences of biochar on the soil microbiota acted in a relatively similar way in the soils they studied, albeit at different levels of magnitude, and so suggested that there is considerable predictability in the response of the soil biota to biochar application[26]. Soil organic carbon an important component of terrestrial ecosystems, does not only affect the soil fertility, but also determines many of the environmental soil functions [27].

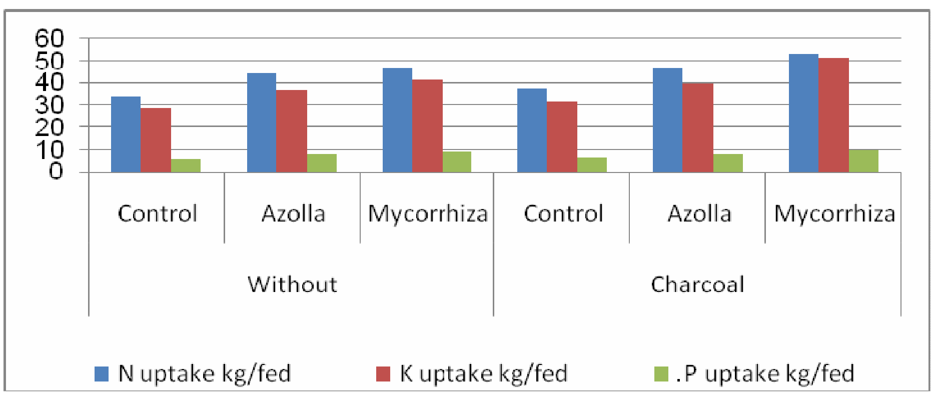

Fig. (2) Effect of interaction between addition of charcoal and inoculation with Azolla or Mycorrhiza on N, P and K uptake of wheat grains.

Conclusions

Our results showed that the addition of charcoal alone had a positive effect on some growth parameters but clearly lower when compared to the use of the biofertilization. There was a significant interaction between addition of charcoal and biofertilization since the highest grain, straw and biological production was obtained when addition of charcoal was combined with Mycorrhiza, demonstrating the beneficial effect of use of biofertilizer inoculation with addition of charcoal on wheat yield.

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