Journal of the Saudi Society of Agricultural Sciences (2016) **15**, 188–194

King Saud University

Journal of the Saudi Society of Agricultural Sciences

www.ksu.edu.sa
www.sciencedirect.com

FULL LENGTH ARTICLE

Bio-chemical properties of sandy calcareous soil treated with rice straw-based hydrogels

Houssni El-Saied [a,*], Omar A. El-Hady [b,*], Altaf H. Basta [a,*], Camilia Y. El-Dewiny [b], Salah A. Abo-Sedera [c]

[a] *Cellulose and Paper Dept., National Research Centre, Dokki 12622, Cairo, Egypt*
[b] *Soil and Water Utilization Dept., National Research Centre, Dokki 12622, Cairo, Egypt*
[c] *Agricultural Microbiology Dept., National Research Centre, Dokki 12622, Cairo, Egypt*

Received 20 September 2014; revised 23 November 2014; accepted 25 November 2014
Available online 3 December 2014

KEYWORDS

Hydrogels;
Rice straw;
Sandy and sandy calcareous soils;
Chemical properties of soil;
Biological activity

Abstract Completely randomized drip irrigated field experiments, with three replications for each treatment, were conducted at El-Saff-Giza Governorate, Egypt to evaluate the beneficial effects of applying the rice straw (RS)-based hydrogels as soil conditioners for sandy calcareous soil. In this respect three successive growing seasons (summer season 2010 using tomatoes vs. custle rock, winter season 2010–2011 using wheat vs. Seds 1 intercropped with onion vs. Giza 20, and summer season 2011 using caw pea vs. Bafb as indicator crops) were carried out. Two rice straw-based hydrogels (with two rates; 2 and 4 g kg^{-1} soil) were examined. After the third growing season some biochemical properties of the soil were determined.

The results obtained show that, application of the investigated hydrogels positively affects biochemical properties of the soil. These effects are assembled in the following: (a) slightly decreasing soil pH, (b) increasing cation exchange capacity (CEC) of the soil indicating improvement in activating chemical reactions in the soil, (c) increasing organic matter (OM), organic carbon, total nitrogen percent in the soil. Because the increase in organic nitrogen surpassed that in organic carbon, a narrower CN ratio of treated soils was obtained. This indicated the mineralization of nitrogen compounds and hence the possibility to save and provide available forms of N to growing plants, (d) increasing available N, P and K in treated soil, and (e) improving biological activity of the soil expressed as total count of bacteria and counts of *Azotobacter* sp., phosphate dissolving

* Corresponding authors. Fax: +20 2 37601877, +20 2 33371719.
E-mail addresses: houssni_nrc@yahoo.com, hel_saied@yahoo.com (H. El-Saied), Omarelhady41@yahoo.com (O.A. El-Hady), Altaf_Basta2004@yahoo.com (A.H. Basta).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2014.11.004
1658-077X

bacteria (PDB), fungi and actinomycetes/g soil as well as the activity of both dehydrogenase and phosphatase.

1. Introduction

Cultivation of sandy calcareous soils is faced by several difficulties namely: low water retention and high infiltration rate, poor structure development, low humus and clay content and loss of nutrients via leaching or deep percolation. High $CaCO_3$ content in the soil causes more difficulties, i.e., surface crusting and cracking, high pH and loss of fertilizers' N, low availability of nutrients particularly P and micro-nutrients (Zn, Fe, Mn and Cu) and nutritional imbalance between some elements (K and Mg) and calcium. Under such severe conditions, desired yield levels are difficult to attain. However they could be as productive as any fertile soil if the right soil water management practices are followed (El-Hady and Abo-Sedera, 2006).

Attention has been paid in the last few decades to use gel forming material as conditioners for sandy and sandy calcareous soils (El-Hady et al., 1981, 1990, 2002; Azzam and El-hady, 1983; Al Darby et al., 1990; Al-Omran and Al-Harbi, 1998; El-Hady and El-Dewiny, 2006; EL-Hady et al., 2010, 2012a,b). In this respect, rice straw (RS)- and other agro-based hydrogels with relatively high absorption capacities for both distilled and Nile water, as well as metal ions were produced by grafting process of rice straw, as undesirable agro waste, by using different initiating systems (El-Saied et al., 2004, 2007, 2011a,b, 2012; Basta et al., 2013). The present work aims to clarify the beneficial effects, of these hydrogels on some bio-chemical properties of the soil.

2. Materials and methods

Completely randomized drip irrigated field experiments, with three replications for each treatment, were conducted at El-Saff-Giza Governorate, Egypt (Steel and Torrie, 1982), during three successive growing seasons. These were summer season 2010 using tomatoes vs. custle rock, winter season 2010–2011 using wheat vs. Seds 1 intercropped with onion vs. Giza 20, and summer season 2011 using caw pea vs. Bafb. Two rice straw (RS)-based hydrogels (G1 and G2), with two rates for each (2 and 4 g kg^{-1} soil) were evaluated as conditioners for sandy calcareous soils, as follows:

2.1. Soil

The soil is a virgin sandy calcareous soil (90.3% sand, 9.7% silt + clay, ~12.0% $CaCO_3$, and 0.06% O.M.), with pH 7.4 and EC 2.2 dSm^{-1}. The main analytical data of the soil are presented in Table 1 (Page et al., 1982; Cottenie et al., 1982; Klute, 1986; Atlas, 2005; Kalembasa and Symanowincz, 2012).

2.2. Irrigation

Two sources of water were alternatively used for irrigation (El-Saff canal water and water of a well dug inside the study area). Analysis of irrigation water used is presented in Table 2. Water was classified as none and slight to moderate restriction on use for the Nile and Well water, respectively (FAO, 1994). Amounts of applied irrigation water were 80% of water requirements for each crop, as calculated using Penman Monteith method (Allen et al., 1998).

2.3. Absorbent materials (hydrogels)

Two prepared RS-based hydrogels, were examined. Description of the preparation conditions, is given below:

- Gel #1, was prepared under grafting conditions: 0.12 H_2O_2/RS ratio, 0.1% ferrous ammonium sulfate, and 2 acrylonitrile/RS ratio, for 3 h, at 50 °C followed by KOH hydrolysis, using AcOH for neutralize the pH-value to ~6–7.
- Gel #2, was prepared by grafting the partially cyanoethylated RS, under the same conditions of hydrogel # 1, using AcOH for neutralize the pH-value to ~6–7.

These examined hydrogels were coded as G1 and G2, and their water absorption capacities, i.e., sat /dry × 100 (w/w) were 7610, and 7061 in distilled water; while 6107, and 3789 in Nile water, respectively (El-Saied et al., 2011a,b; Basta et al., 2013).

2.4. Experimental treatments

Five conditioning treatments were evaluated, i.e., non-conditioned soil (treatment #1), soils conditioned with the hydrogel G1 at the rates of 2 and 4 g kg^{-1} dry soil (treatments #2 and #3) and soils conditioned with the hydrogel G2 at the same rates of G1 (treatments # 4 and # 5, respectively).

2.5. Evaluation parameters

At the end of the 3rd growing season (December, 2011), some bio-chemical properties of the soil (for each treatment), were determined. For the chemical properties and nutritional status of the soil, soil pH determined in 1:2.5 soil water suspensions, organic matter content (OM), cation exchange capacity (CEC), total organic carbon (OC) as well as available nitrogen, phosphorous and potassium were carried out according to Page et al. (1982) and Cottenie et al. (1982).

While for the biological properties of the soil, total bacterial count determined using Nutrient Agar medium, Azotobacter count determined using Azotobacter Agar modified of medium, phosphate dissolving bacteria count (PDB) determined using Bacillus Agar 1/4 strength medium, Actinomycetes count determined using Soil Extract Glucose Yeast Extract Agar medium and total fungal count determined using Aureomycin® Rose Bengal Glucose Peptone Agar medium were carried out according to Atlas, 2005. Dehydrogenases

Table 1 Analytical properties of El-Saff sandy calcareous soil.

Sand%		Silt 20–2 u%	Clay < 2 u%	Texture
Course > 200 u	Fine > 200–20 u			
1 – Mechanical analysis:				
67.5	22.8	5.0	4.7	Sand

pH 1:2.5	EC 1:5 dSm^{-1}	$CaCO_3$ %	CEC C mol kg^{-1}	O.M %	Macronutrients ($\mu g\ g^{-1}$)					
					Total			Available		
					N	P	K	N	P	K
2 – Chemical analysis:										
7.4	2.2	11.95	4.48	0.06	65	738	1015	32	6	55

Bulk density ($Mg\ m^{-3}$)	Total porosity (%)	Water[a] holding capacity, (%)	Field[a] capacity (%)	Wilting[a] percentage	Hydraulic conductivity ($m\ day^{-1}$)	Mean diameter of soil pores (u)
3 – Hydro-physical analysis:						
1.63	38.5	22.8	7.11	1.22	7.3	16.7

Total bacterial count × 10^3	Azotobacter count × 10^2	Phosphate dissolving bacteria count × 10^2	Total fungi × 10^2	Actinomycetes × 10^2	Activity of dehydrogenises[b]	Activity of dehydrogenises[c]
Biological analysis						
76.7	34.6	11.2	5.8	13.2	2.0	1.6

[a] On weight basis.
[b] ml H_2/g dry soil/24 h.
[c] mg/P_2O_3/100 g soil after 24 h incubation.

Table 2 Analyses of irrigation water used.

Source	pH	EC dsm−1	Soluble cations (meq/l)				Soluble anions (meq/l)			
			Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^{--}	Cl^-	SO_4^{--}
Canal	7.53	0.47	1.36	0.07	3.36	2.04	0.3	–	0.36	2.17
Well	7.05	1.35	8.3	0.2	9.0	6.5	0.02	3.6	5.4	14.6

Fe = traces < 3 $\mu g\ g^{-1}$.

and phosphatase activities were determined according to Kalembasa and Symanowincz (2012).

3. Results

3.1. Effect of RS-based hydrogel on some chemical properties of treated soil

Comparing the initial soil chemical analysis before starting the experiment (Table 1) to the analysis at the end of the 3rd growing season (Table 3) and with only one exception, i.e., soil pH it is clear that, studied soil chemical properties were improved due to plantation during this period. As can be seen, soil plantation raises its CEC by ~6%, OM and OC by ~300%, total N by 41%, available N, P and K by 30.6, ~600 and ~350%, respectively. Therefore, C/N ratio was decreased from 10.6 before plantation to be 9.7:1 at the end of the 3rd growing season.

More improvement in the studied soil properties by varying degrees was noticed due to soil conditioning (Table 3).

Regarding soil pH, all examined conditioning treatments provided a slight decrease in the pH values of the soil. The decrease in soil pH was calculated to be 0.1 and 0.13 units by applying 2 and 4 g of G1 kg^{-1} soil; while using 2 and 4 g of G2 kg^{-1} soil pH lowered by 0.09 and 0.11 units, respectively. Moreover, data refer that, treating the soil with hydrogels raises its CEC, and consequently overcomes the limitations of soil fertility, as a result of low cation exchange capacity (CEC) of the soil, since many soil properties such as adsorption of water, nutrients and the attraction forces between particles are all surface phenomenon. Values of CEC were increased with increasing the application rate of hydrogels. Where, using 2 g and 4 g of G1 kg^{-1} soil as soil conditioner raised its CEC by 16.1% and 22.4%, respectively, compared to the non-conditioned soil; while, CEC values of conditioned soil with the hydrogel G2 were 1.14 and 1.20 times that of the untreated soil, using 2 and 4 g G2 kg^{-1} soil, respectively.

With respect to soil organic matter treating the soil with the hydrogel leads to an increase in its carbon content, where, G1 at the rates of 2 g and 4 g kg^{-1} soil increased organic carbon content of the soil to be 2.0 and 2.55 times that of untreated soil, respectively. While, the organic carbon content of treated soil with 2 g or 4 g kg^{-1} soil of the hydrogel G2 was 1.8 or 2.25 times that of the non-conditioned soil, in sequence.

Similarly, total nitrogen and organic nitrogen content took the same trend of organic carbon (OC) content. Comparing these contents of the hydrogels treated soil with

Table 3 Effect of RS-based hydrogels on some chemical properties of sandy calcareous soil after three successive growing seasons.

Treatments			pH 1:2.5 H_2O	Organic C ($\mu g\ g^{-1}$)	CEC C mol kg^{-1}	Specific surface area ($m^2 g^{-1}$)	Available macronutrient ($mg\ kg^{-1}$ soil)				Total N ($\mu g\ g^{-1}$)	C/N ratio
No.	Hydrogels						N		P	K		
							NH_4^+	NO_3^-				
1	–	–	7.40	1160	7.15	13.99	14.2	27.6	41.6	250.1	162.0	9.7
2	G1	2 g kg^{-1}	7.30	2320	8.30	16.80	16.6	33.4	52.4	356.3	582.3	4.4
3	G1	4 g kg^{-1}	7.27	2958	8.75	17.70	17.9	39.3	63.8	415.2	640.9	5.0
4	G2	2 g kg^{-1}	7.31	2088	8.15	16.75	16.0	32.6	52.0	333.3	498.1	5.0
5	G2	4 g kg^{-1}	7.29	2610	8.60	17.60	17.5	38.1	60.0	396.4	597.6	4.8

Table 4 Effect of RS based hydrogels on some biological properties of a sandy calcareous soil after three successive growing seasons.

Treatments			Total bacterial count × 10^6	Azotobacter × 10^4	Phosphate dissolving bacteria × 10^4	Total fungi × 10^4	Actinomycetes × 10^4	Activity of dehydrogenises[a]	Activity of phosphatase[b]
No.	Hydrogels								
1	–	–	92.7	20.1	15.3	17.1	20.1	21.4	18.9
2	G1	2 g kg^{-1} soil	160.0	35.4	45.2	29.7	25.7	37.4	35.9
3	G1	4 g kg^{-1} soil	205.0	39.2	48.6	32.2	36.9	42.1	40.7
4	G2	2 g kg^{-1} soil	124.5	28.4	30.4	22.7	24.5	30.5	28.7
5	G2	2 g kg^{-1} soil	152.0	32.1	40.1	26.9	29.2	35.5	34.8

[a] ml H_2/g dry soil/24 h.
[b] mg P_2O_5/100 g soil after 24 h incubation.

the non-conditioned soil, it was clear that, the total N were highly increased to be 3.6 and 4.0 times with 2 g and 4 g G1 kg^{-1} soil. Relevant values for organic N were 4.4 and 4.9 times. Increments in total N due to applying 2 and 4 g G2 kg^{-1} soil were 207.5% and 268.9%, respectively. Moreover, the increments in organic nitrogen over those of the non-conditioned soil arranged in the same manner were 274.0% and 350.9%, respectively. Because the increase in organic carbon is far beyond that of total nitrogen, therefore carbon nitrogen ratios are much narrower. C:N ratio of the non-conditioned soil was 9.7:1. It decreased to be 4.4:1 and 5.0:1 by treating the soil with 2 and 4 g of the gel G1, in sequence. Relevant values for G2 were 5.0:1 and 4.8:1. Such decrease in C:N ratio could be referred to the mineralization of organic nitrogen compounds in the soil and the possibility to save and provide available forms of N to growing plants.

It is well known that the availability of nutrients in sandy calcareous soils is low, where the available N, P and K in the non-conditioned soil were 41.8, 41.6 and 250.1 mg kg^{-1} soil, respectively. A considerable increase in the availability of these nutrients was noticed due to soil conditioning. Using 2 g or 4 g of the hydrogel G1 kg^{-1} soil, as a conditioner, raised its nutrient availability by 19.6% or 36.8% for N, 26.0% or 53.4% for P and 42.5% or 66.0% for K. Relevant values for the hydrogel G2 (when applied at the two rates of G1) were 16.3% or 33.0%, 25.0% or 44.2% and 33.3% or 58.5% for N, P and K, in sequence.

3.2. Effect of RS-based hydrogel on some biological properties of treated soil

Microorganisms such as bacteria, fungi and actinomycetes influence profoundly the physical, chemical and the biological properties of soils. Activities of such organisms include the decomposition of plant residues and other organic materials, as well as the formation of humus, which is regarded as the most chemically and physically active group of compounds in the soil. One result of these processes of decay is the release of organic forms of essential plant nutrients, such as nitrogen, phosphorus and sulfur. Subsequently still other micro-organisms can oxidize, reduce and otherwise change the state of the nutrient elements in the soil. These changes have a profound influence on plant growth and otherwise affect soil properties in addition to the role of organic fertilizers as amendment for improving physical and chemical characteristics of the soil, which in turn reflected on rhizosphere micro flora, plant growth and yield (Brady, 1990; EL-Hady and Abo-Sedera, 2006; EL-Hady et al., 2010). Increasing the low number of micro-organisms mentioned above, i.e. bacteria, fungi and actinomycetes, in sandy soil indicates an improvement in its biological fertility.

Since most of the biological reactions in the soil are enzymatic changes, therefore enzyme activity could be considered as another parameter to characterize the biological activity of the soil. In this respect, both dehydrogenase and phosphates activities were essayed.

Comparing the initial soil biological properties before starting the experiment (Table 1) to the analysis at the end of the 3rd growing season (Table 4), it is obvious that such soils could be considered inert since their biological activity is very low.

As can be seen soil plantation for three successive growing seasons raised all studied biological properties to be 1209, 58, 137, 295 and 152 folds than those of the initial soil and before plantation for total bacterial counts, counts of *Azotobacter* sp., phosphate dissolving bacteria, total fungi and actinomycetes, respectively. Moreover, the activity of both dehydrogenase and phosphatase was increased to be 10.7 and 11.8 folds that of the initial soil before plantation in sequence. More improvement in the studied soil properties was noticed due to soil conditioning (Table 4).

After three successive growing seasons it was clear that, applying 2 g of G1 to each 1 kg soil of the plant pit led to an increase in the number of total bacteria, *Azotobacter* sp., phosphate dissolving bacteria (PDB), fungi and actinomycetes by 72.6%, 76.1%, 145.4%, 73.7% and 27.9%, respectively. Such increases were 121.1%, 95.0%, 217.6%, 88.3% and 83.6%, respectively when the rate of applied hydrogel was doubled to be 4 g kg^{-1} soil. Applying 2 g kg^{-1} soil of examined hydrogel G2 conditioner, it increased the aforementioned numbers by about 34.3% for bacteria, 41.3% for *Azotobacter* sp., 98.7% for PDB, 32.7% for fungi and 21.9% for actinomycetes. Values for 4 g kg^{-1} soil arranged in the same manner were 64.0, 59.7, 162.1, 57.3 and 45.3%, respectively.

Regarding the effect of applied hydrogels on enzyme activity in conditioned soils, data (Table 4) indicate the increase in the activity of dehydrogenase and phosphatase by soil conditioning. Applying 2 g kg^{-1} soil of the hydrogel G1 to the plant pit raised the biological activity of soil enzymes by 74.8% for dehydrogenase and 89.9% for phosphatase. More increase in enzyme activity was obtained, when higher rate of G1(4 g kg^{-1} soil) was incorporated in the soil to be 96.7% and 115.3%, relative to that of untreated soil for both enzymes, respectively. Conditioning the soil with G2 also increased enzyme activity in the soil but with lower degree. Increments in enzymes activity due to applying 2 g and 4 g kg^{-1} soil were 42.5% and 65.9% for dehydrogenase and 51.9% and 84.1% for phosphatase, in sequence.

4. Discussion

Producing highly water absorbent hydrogels using rice straw (RS) as undesirable bio-waste, which adds high economic value, contributes in reducing the environmental impact of waste disposal and most importantly provides a potentially inexpensive alternative bio-polymer to the existing commercial hydrogels from petro-chemical origins. The prepared RS hydrogels do not possess linear chain structures but the chains are rather cross linked to form a three dimensional network. Depending on the synthesis conditions and type and density of covalent bonds that form cross linking, these hydrogels are capable of absorbing hundreds of times, their weight in water and can expand greatly when hydrated and are claimed to remain active for a much longer time (El-Saied et al., 2011a).

The beneficial change in studied bio-chemical properties, nutritional status of the soil and consequently plant growth and yields due to the addition of RS-based hydrogels besides the contribution effect of these hydrogels on improving the hydro-physical properties of the soil could be attributed to the following: (1) the prepared hydrogels are viewed as analogous to soil organic matter and the study of soil particle–polymer binding mechanisms provides an insight into mechanisms by which soil organic matter binds soil particles together leading to the formation of stable aggregates (El-Hady and Abo-Sedera, 2006). The increase in OC content in the conditioned soil besides ON, leads to several beneficial effects on the other soil properties. The de-compensation of organic matter by micro-organisms, i.e., fungi, actinomycetes, bacteria and yeasts under suitable conditions of humidity, aeration and temperature produces a large number of polymeric molecules such as polysaccharides, organic acids, humus, amino-acids, lignin and other more complicated compounds (Charreau, 1975; Fallet et al., 1981; Elkins et al., 1984; Insam, 1989). This is of peculiar importance for the sandy and coarse textured soils in which population of microorganisms are relatively low. The rate of decomposition of organic materials in the soil depends primarily on its physic-bio chemical properties (the substrate factors), and on the chemical and physical properties of the soil, which determine the nature of the environment for microbial growth and metabolism (the soil factors). Substrate factors would include: chemical composition, C/N ratio, lignin content, particle size or state of subdivision, nature of the indigenous micro – flora and biochemical oxygen demand (BOD), i.e., oxygen consumed by microorganisms in the process of decomposing organic materials under standard conditions and during a specific period of incubation. Soil factors would include: temperature, oxygen supply, soil moisture content, soil available nutrients and soil texture and structure (Parr, 1975).

(2) Increasing the low surface area as well as the low exchange capacity of the soil and in turns its effects on activating other chemical reactions of inert sand. It is essentially due to the high cation exchange capacity of hydrogels that reached in our study to 1000 ± 50 (mol kg^{-1}), if compared to that of common soil colloids responsible for most soil CEC such as clays (< 100 mol kg^{-1}) or humus (100–300 (mol kg^{-1}) (El-Saied et al., 2011b).

(3) Hydrogels have the ability to absorb a lot of water in soil, the existing nutrients in the soil which dissolve in soil solution can be absorbed into it or on its surface. At the same time absorbed nutrients can be released or desorbed slowly through the exchange of free water or minerals between soil solution and RS-based hydrogels. Therefore they improve nutrient retention abilities and minimize the loss of such nutrients by leaching or deep percolation. Hence they remain in soil within the reach of the plant root system i.e. in available forms for a long period (El-Hady et al., 1991; Ouchi et al., 1991; Martin et al., 1993; Boatright et al., 1995; El-Saied et al., 2011b).

(4) Quantities of retained cations and anions differ according to the approach of grafting of RS, as step to prepare hydrogels with relatively high COO^- groups together with amide groups (El-Saied el al., 2010). Accordingly, modes of action could be summarized as follows: (a) adsorption of cations or/and anions of the soil or fertilizer solutions on the appositely internal or external changes of gel molecules, (b) cations and or anions exchange between the associated cations (K^+) or the associated anions with gel (COO^-) and ions in the soil, soil solution and fertilizer solution. Previous studies (El-Saied et al., 2011b) indicated considerable part of such associated anions and cations with gel molecules were easily desorbed, (c) hydrogels also affect nutrient uptake indirectly by increasing moisture in the soil and subsequently ion mobility. Therefore, the availability of some nutrients either present in soil or added in the form of relatively insoluble fertilizers such as phosphates will be increased (El-Hady et al., 2003) with the partial retardation of gas exchange between soil and atmosphere as a result of increasing soil moisture and decreasing soil macro-porosity may favor transformation of some plant nutrients, such as No_3^- and some micro-nutrients to their reduced forms i.e. NH_4^+ and other forms of micro-nutrients having lower equivalency, hence decreasing the loss of No_3^-

by leaching and increasing the availability of other nutrients (Boatright et al., 1995).

There are other benefits for using RS-based hydrogels as soil conditioners to be taken into consideration and these are: (i) the small quantities of hydrogels needed for soil conditioning if composed with the huge quantities of applied manures and composts. (ii) Quantities of irrigation water saved during the growing season. In our study 20% of irrigation water was saved. This means that the planted area could be increased by the same quantity of irrigation water saved. (iii) The easiness of hydrogel application taking into consideration that applied hydrogels if compared with other types of soil conditioners do not need special instrumentation for their distribution in the soil nor rehydration or post drying of the soil before their plantation, besides saving the cross-linkers which are essential for the in-solubilization of water soluble polymers.

5. Conclusions

As expected the properties of untreated calcareous sandy soil adversely affect plant growth nutrient content and both water and fertilizer use efficiency by plants. Treating the soil with examined RS based hydrogels, besides the improvement in the hydrophysical properties of such kind of soil, it led to provide the following improvements:

– Improving chemical properties and nutritional status of the soil through (i) lowering pH and its effects on nutrient availability (ii) increasing organic matter content, organic nitrogen percent in the soil, (iii) increasing available N, P and K in treated soil, as well as the activity of both dehydrogenase and phosphatase.
– Improving biological activity of the soil expressed as total count of bacteria i.e. *Azotobacter* sp., phosphate dissolving bacteria (PDB), fungi and actinomycetes/g soil and the activity of both dehydrogenase and phosphatase.

Acknowledgments

This research work was carried out under Grant from Science and Technology Development Fund (STDF), sponsored by the Egyptian Ministry of High Education and Scientific with Project ID: 370.

References

Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration guidelines for computing crop water requirements. In: FAO Irrigation and Drainage Paper, No. 56. FAO, Water Resources, Development and Management Service, Rome, Italy.

Al-Omran, A.M., Al-Harbi, A.R., 1998. Improvement of sandy soils with soil conditioners. In: Wallace, A., Terry, R.E. (Eds.), Handbook of Soil Conditioners Substances that Enhances the Physical Properties of Soil. Marcel Dekker Inc., NY, USA, pp. 363–384.

Al Darby, A.M., Mostafa, M.A., Al-Omran, A.M., 1990. Effect of water quality on infiltration of loamy sand soil treated with three gel conditioners. Soil Technol. 3, 83–90.

Atlas, R.M., 2005. Handbook of Media for Environmental Microbiology, second ed. Taylor and Francis gp, CRC Press, NY, USA.

Azzam, R., El-Hady, O.A., 1983. Sand-RAPG combination simulating fertile clay in soil. II: Structure stability and maintenance. III: Water preservation. In: Symposium of Isotope and Radiation Techniques in Soil Physics and Irrigation Studies, IAEA and FAO, Alex. en province, France, 18–22 April, 1983. IAEA-SM-167/15: 330–335 for part II and 336–342 for part III.

Basta, A.H., El-Saied, H., Hady, El.-, El-Dewiny, C.Y., 2013. Evaluation of rice straw-based hydrogels for purification of wastewater. Polym. Plast. Technol. Eng. 52, 1074–1080.

Boatright, J.L., Zajicek, J.M., Mackay, W.A., 1995. Soil water, NH_4^+ and NO_3^- retention in low-maintenance annual landscape, beds amended with a hydrophilic polymer. HortScience 30 (4), 896.

Brady, N.E., 1990. The Nature and Properties of Soils, 11th ed. Macmillan Publication, New York, USA.

Charreau, C., 1975. Organic mater and bio-chemical properties of soil in the dry tropical zone of West Africa. In: Organic Materials as Fertilizers, FAO Soils, Bulletin No. 7. pp. 313–335.

Cottenie, A., Verloo, M., Kiekens, L., Velghe, G., Camerlynck, R., 1982. Chemical Analysis of Plants and Soils. Lab. Agrochem. State University Ghent, Belgium.

El-Hady, O.A., Tayel, M.Y., Lotfy, A.A., 1981. Super gel as a soil conditioner. II: Its effect on plant growth, enzymes, activity, water use efficiency and nutrients uptake. Acta Horticulturae 119, ISHS: 257–266.

El-Hady, O.A., Pieh, S.H., Osman, S., 1990. Modified polyacrylamide hydrogels as conditioners for sandy soils. III: Influence on growth, water and fertilizers use efficiency by plants, Egypt. J. Soil Sci. 30 (3), 423–432.

El-Hady, O.A., Abd El-Hady, B.M., Abbady, K.A., 1991. Acrylamide hydrogels and bentonitic clays as means for reducing the loss of nitrogen added to sandy soils through fertigation (columns experiment), Egypt. J. Appl. Sci. 6, 412–425.

El-Hady, O.A., Abdel Hady, B.M., Rizk, N.A., El-Saify, E.S., 2003. The potentiality for improving plant-soil-water relations in sandy soils using some synthesized AmNa (or K) ATEA hydrogels. Egypt J. Soil Sci. 43, 547–566.

El-Hady, O.A., Adam, M.S., Abdel el-Kater, A.A., 2002. Sand-compost-hydrogel mix for low cost production of tomato seedings. Egypt J. Soil Sci. 42, 467–782.

El-Hady, O.A., El-Dewiny, Camilia Y., 2006. The conditioning effect of composts (natural) or/and acrylamide hydrogels (synthesized) on a sandy calcareous soil: 1-growth response, nutrients uptake, water and fertilizers use efficiency by tomato plants. J. Appl. Sci. Res. 2 (11), 890–898.

El-Hady, O.A., Abo-Sedera, S.A., 2006. Conditioning effect of composts and acrylamide hydrogels on a sandy calcareous soil. II: Physico-biochemical properties of the soil. Int. J. Agric. Biol. 8 (6), 876–884.

EL-Hady, O.A., Shaaban, S.M., El-Dewiny, Camilia Y., 2010. The conditioning effect of composts or/and water absorbent polymers on some physico-biochemical properties of a sandy calcareous soil after cucumber plantation. Egypt J. Soil Sci. 50 (1), 51–69.

EL-Hady, O.A., Abo-Sedera, S.A., BastaEl-Saied H.,, A.H., El-Saied, H., 2012a. The role of rice straw-based hydrogels on some soil microorganisms strains. Bio 1, 78–84.

EL-Hady, O.A., Shaaban, S.M., Wanas, Sh.A., 2012b. Effect of hydrogels and organic composts on soil hydrophysical properties and in production of tomato. Acta Horticulturae 933, ISHS: 115–122.

ElKins, N.Z., Parker, L.W., Aldon, E., Whitford, W.G., 1984. Responses of soil biota to organic amendments in stripmore spois in North-Western New Mexico. J. Environ. Qual. 13 (2), 215–219.

El-Saied, H., Waley, A.I., Basta, A.H., El-Hadi, O.A., 2004. High water absorbents from lignocelluloses. II: Novel soil conditioners for sandy soil from lignocellulosic wastes. Polym. Plast. Technol. Eng. 43, 770–795.

El-Saied, H., Basta, A.H., Waley, A.I., El-Hadi, O.A., 2007. High water absorbents from lignocelluloses. Part III: Upgrading the utilization of old news paper (ONP) in agronomic applications. Polym. Plast. Technol. Eng. 46, 311–319.

El-Saied, H., Basta, A.H., Waley, A.I., El-Hady, O.A., El-Dewiny, C.Y., Abo-Sedera, S.A., 2011a. Upgrading the utilization of rice straw as low cost material for production of hydrogels for agronomic application, Egyptian Patent No. 2012092011 (submitted for publication).

El-Saied, H., El-Dewiny, C.Y., Basta, A.H., El-Hady, O.A., 2011b. Evaluation of rice straw (RS)-based hydrogels as preserving agents for fertilizers in sandy soil. Egypt. J. Soil Sci. 51 (1), 129–145.

El-Saied, H., Basta, A.H., Waley, A.I., El-Hady, P.A., Abo-Sedera, S.A., Abdel-Kader, A.A., El-Dewiny, C.Y., Shaban, S. M., 2012. Enhancing the utilization of rice straw as potential low cost superabsorbent materials. In: 10th Int. Conf. Egypt Soil Science Society (ESSS), 5–8 November, 2012, America, Alex., Egypt.

Fallet, R.H., Larr, S., Donahue, R.L., 1981. Fertilizer and Soil Amendments. Prentice-Hall Inc., Englewood Cliffs, New Jersey, USA.

FAO, 1994. Water quality for agriculture: irrigation and drainage paper no. 29. FAO, Rome, Italy.

Insam, H., 1989. Improvement of fly-ash reclamation with organic, organo mineral and mineral amendments. In: Proceedings of Conference Reclamation, A Global Perspective, Calgary, Alberta, August 27–31.

Kalembasa, S., Symanowincz, B., 2012. Enzymatic activity of soil after applying various waste organic materials, ash and mineral fertilizers. Pol. J. Environ. Stud. 21 (6), 1635–1641.

Klute, A., 1986. Methods of Soil Analyses, second ed. American Society of Agronomy Inc., Soil Science Society of America, Madison, Wisconsin, USA.

Martin, C.A., Ruter, J.M., Rober, R.W., Sharp, W.P., 1993. Element absorption and hydration potential of polyacrylamide gels. Commun. Soil Sci. Plant Anal. 24 (5–6), 539–548.

Ouchi, S., Kamada, E., Matsue, N., Nishikawa, A., 1991. Soil improving effect of a super-water absorbent polymer (part 3). Water retention and ion exchange of the polymer. Japan. J. Soil Sci. Plant Nutr. 62 (5), 487–492.

Page, A.L., Miller, R.H., Keeny, D.R. (Eds.), 1982. Methods of Soil Analysis. Part 2: Chemical and Biological Properties. American Society of Agronomy Inc., Madison, Wisconsin, USA.

Parr, J.F., 1975. Chemical and biological consideration for land application of agricultural and municipal wastes. In: Organic Material as Fertilizers, FAO Soils, Bulletin No. 27, pp. 227–252.

Steel, R.G.D., Torrie, J.H., 1982. Principles and Procedures of Statistics A. Biometrical Approach, second ed. McGraw-Hill Co., NY, USA.