Impact of Soil Amendments Application for Ameliorating the Hydraulic Properties and Solute Transport of Coarse - Textured Soils

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ABSTRACT

Laboratory experiments established to investigate the effect of different amendments on the hydraulic properties and solute transport in saturated sandy soil columns. Three soil amendments were used, namely, banana peel ground, chitosan, and acryhope polymer. Two amounts of each amendment added to the soil as 10 and 20 g Kg^{-1} air dried soil for banana peel ground and Chitosan, and 0.1 and 0.2 g Kg^{-1} air dried soil for acryhope polymer. Control treatment (soil only) was benefited. The treatments were homogenously mixed with the soil then packed in PVC columns under saturated steady state condition. A solution $CaCl_2$ (0.01 N) + K_2SO_4 (100 ppm K) was applied to soil columns until the relative concentration (C/C_o) reach unity. Effluents were collected to measure water and nutrient transport. The results showed that all amendments increased soil water content, decreased saturated hydraulic conductivity (Kh) and decreased pore water velocity (PWV) compared with control. The best amendment was banana peel ground 2% in decreasing Kh and PWV, so the soil will hold more water. In addition, banana peels 2% is the effective amendments that increased potassium availability in soil, through retarding it. It is concluded that use of amendment in sandy soil to improve soil hydro-physical properties. Addition of amendments to soil reduces leaching of nutrient and has an economical benefit and environmental impact. Use of banana peels has many advantages such as enhancement of soil properties and it is a good way in waste management.

Keywords:- Banana peel ground, chitosan, sandy soil, hydraulic properties, superabsorbent polymer, solute transport.

INTRODUCTION

Water scarcity has become a major limitation for crop productivity especially in arid and semi-arid areas. Drought occurrences are increasing dramatically all over the world and the prediction shows it will increase in the future (Sheffield et al., 2018). So, ways to conserve water and improve water availability are urgently, required. Sandy soil has poor physical and chemicals properties such as structure-less soil, poor nutrients, and low water holding capacity (WHC). The addition of amendments is one of the techniques used to improve hydro-physical and chemical properties of soils particularly, coarse textured soil.

Organic amendments such as plant residues, compost, sewage sludge and animal manure that enhance aggregate stability, control infiltration rate of porous media, and source of plant nutrients in arid and semi-arid lands (Martens et al., 1992; Tejada et al., 2008; Mirzaei Aminiyan et al., 2015; Saad, 2017). Also Chitosan is an organic amendment which obtained by deacetylation of chitin, It has been widely used in numerous applications because of its biodegradability and non-toxicity quality, uses of chitosan can lower ecological stress due to drought and soil deficiencies, strengthen seed vitality, improve yields, insecticides, fungicides (Hassan and Chang, 2017). Using of bio-waste amendments as banana peels has many advantages through get ride off waste in addition to its effect in enhancement of soil characteristics. Although there are several research in which banana peel was used as compost or biochar, there are very little research in which banana peel was used as is (Sial et al., 2019). Inorganic amendments such as polymers are solution to improve water and nutrient holding capacity (Azzam, 1980; Emami & Astaraei, 2012). Synthetic amendments as Super absorbent polymers (SAPs) can repeatedly absorb and retain water entering the soil and to reduce deep seepage losses and then gradually release the water to the plants as the soil dries and the plants root pressure increases (Yang et al., 2014). Sap uses in arid and semi-arid areas to maintain water content (Chen et al., 2016) and increases water use efficiency (Liao et al., 2016). Super absorption polymers are added to the soil at a concentration between 0.1 to 0.5% by weight (Buchholz and Graham, 1998). Below this rate, the effect of the soil additive is irrelevant, and above this rate the soil can become too spongy when it is saturated.

The main objective of the study was trying to conserve more water in sandy soil through the application of different types of amendments to soil. And investigation the effects of amendments (chitosan, Acrypole polymer and banana peels ground) on hydraulic properties in sandy soil; and solute transport (chloride and potassium) under saturated conditions.

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MATERIAL AND METHODS

Soil and amendments preparation

Soil was taken from the top 20 cm of El Bostan region, Egypt. The soil was air-dried then passed through 2 mm sieve. Soil hydro-physical properties were determined according to Black et al. (1965). Particles size distribution analysis was determined by dry sieving for large particles (Gee and Bauder, 1986) and the hydrometer method was used for the fine soil fraction (Black *et al.*, 1965). Soil moisture content (θ) was measured by the gravimetric method (Reynolds, 1970). Soil bulk density determined by soil core method. Saturated hydraulic conductivity (K_s) measured using the constant head method (Klute and Dirksen, 1986). Soil chemical properties were determined according to Sparks (2020). Amendments used in this study were banana peel ground, polymer and chitosan. Banana peel amendment was prepared by air drying of banana peel till reaching black color then grinded, finally passed through 2 mm sieve. Chitosan is bought from ROTH Company. Chitosan powder which used is low molecular weight, from crab shells, chemical structure is Poly-(1.4-B-D-glucopyranosamine); 2-Amino-2-deoxy-(1->4)-B-D-glucopyranan. Polymer was cross-linked sodium polyacrylate, known as Acryhope (Nippon Shokubai Company, japan) (0.2-1 mm). Six soil amendments mixtures were used, in addition to the control that was soil without any amendment. The treatments were: Control, banana peel 1% (by weight, bp 1%), banana peel 2% (bp 2%), chitosan 1% (ch 1%), chitosan 2% (ch 2%), polymer 0.1% (poly 0.1%), and polymer 0.2% (poly 0.2%)

Leaching experiments

Seven soil columns with approximately 12 inches height and 2 inches inner diameter conducted and packed by adding a thin layer of coarse quartz in the bottom of the column, soil gradually added inside the column until the column filled with uniform bulk density (1.7 Mg/ m^3). It noticed that there was a little change in the value of bulk density because of adding amendments. The surface of soil in the columns covered with a thin layer of coarse quartz sand to avoid splashing. The soil columns were slowly with distilled water by capillary (upward flux). Then the saturated soil columns subjected to a steady downward flow of distilled water to leach the soil column until the leachate EC reaches 0.13 ds/m. A solution $CaCl_2$ (0.01 N) + K_2SO_4 (100 ppm K) was applied to soil column until the relative concentration (C/C_o) reach unite. Where C is the solute concentration which leached with time also called absolute concentration, C_o the concentration of applied solute. The leachate samples were collected at different time and analyzed for concentrations of Cl^- and K. Sampling time and its volume was being recorded. The saturated hydraulic conductivity was measured under constant head and steady state flow.

RESULTS AND DISCUSSION

The particle size analysis result of the used soil was 92% sand, 2% silt and 6% clay which classified the soil texture as sandy soil. Table (1) represented the particle size distribution of soil and soil mixtures. The major fraction ratio was from 1 to 0.25 mm diameter. The soil pH was 8.1, The EC was 1 ds/m, soluble potassium is 40 ppm, and soluble chloride is 50 ppm.

Table 1. Dry sieve analysis and bulk densities (Db) of soil and soil amendment mixtures

Treatment	Particle size distribution, Diameter (mm)						Bulk density (gm/cm3)	Total porosity (%)
	Fractions %							
	2-1	1-0.5	0.5-0.25	0.25-0.125	0.125-0.053	<0.053		
Control	14.82	29.46	30.2	18.8	6.31	0.32	1.73	0.20
bp 1%	14.13	30.88	30.69	19.29	4.68	0.32	1.75	0.30
bp 2%	13.43	32.29	31.15	19.76	3.03	0.33	1.75	0.32
Ch 1%	14.89	29.38	30.12	18.81	6.47	0.33	1.74	0.26
Ch 2%	14.60	29.29	29.90	18.90	7.00	0.31	1.72	0.27
Poly 0.1%	17.53	32.14	28.68	16.87	4.48	0.31	1.72	0.36
Poly 0.2%	20.30	34.77	27.12	14.91	2.60	0.31	1.60	0.49

Effect of amendments on soil physical properties

Bulk density

The bulk density and the total porosity of the soil and soil mixtures showed in Table (1). The aimed bulk density was approximately 1.7 gm/cm^3 for all mixtures and control columns used in this work, a slight change occurred in some columns after the initial condition due to water flow inside the column and rearrange of soil particles (i.e., upward saturation, followed by downward flow with 0.01 M $CaCl_2$) which resulted in recalculation of the bulk density. But it was slightly change in bulk densities, except poly 0.2% column. The bulk density in poly 0.2% reduced from 1.7 to 1.6 gm/cm^3(Table 1). Bai et al. (2010) discovered that the application of SAPs can reduce soil bulk density and increased porosity. All amendments increased the total porosity compared to control. Poly 2% had the greatest effect in increasing porosity more than double in comparison with control.

saturated volumetric water content (θv)

Soil management practices, influence the capacity of soil to store and supply water to crop.

All amendments increased the saturated volumetric water content (Figure.1) compared with control. Polymer 0.2% was recorded the highest value of saturated volumetric 0.49 nearly doubled the volumetric water content compared to the control 0.20. Polymers increased water content because its ability to adsorb high amount of water. Akhter et al. (2004) found that the polymer amendment was effective in improving soil moisture accessibility and accordingly increased plant growth. The expansion of polymer at the rate of 2 g/kg increased the water holding capacity of coarse sand from 171 to 402% (Johnson, 1984). Further, hydrogel expansion improved water storage properties of permeable soils. The Same result was found by Yang et al. (2014) and Liao et al. (2016), where an increase of soil saturated water content with addition of polymer through improving water retaining capacity in soil. Slightly changing was happened when increasing the percent of banana peel from bp1% to bp 2%, also there was the same in increasing the percent of ch 1% to ch 2%. These results showed that soil moisture content of sandy soil improved with addition of all amendments. So the best application rate in increasing water content in soil was poly 0.2%.

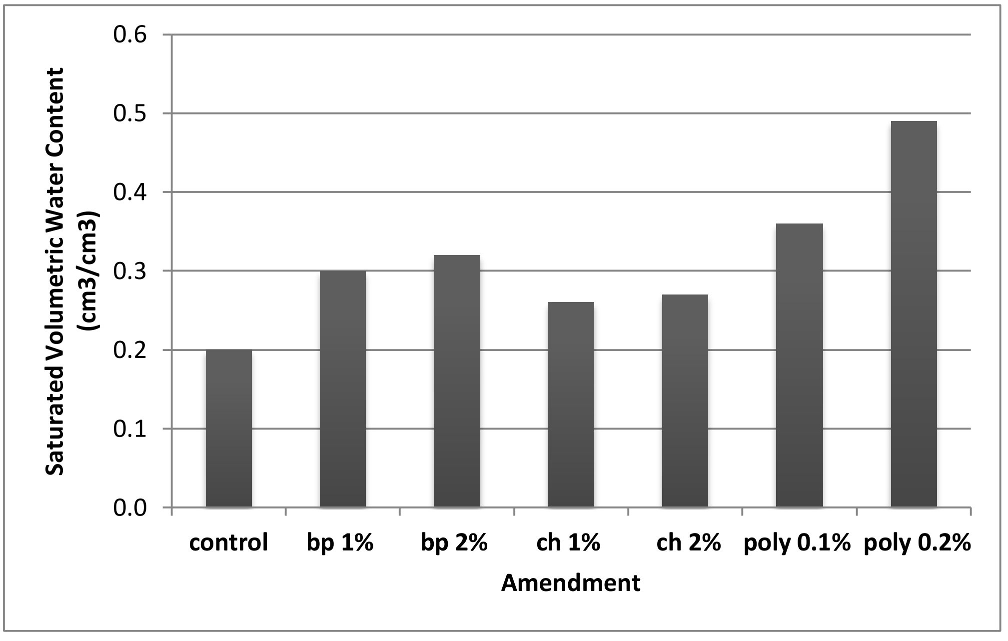

Fig. 1. Effect of soil amendments on saturated volumetric water content in soil column

Effect of soil amendments on saturated hydraulic conductivity (K_s)

All amendments decreased the saturated hydraulic conductivity (Figure 2). Where all amendments increased the total porosity of the soil (Table 2) compared with control, therefore the hydraulic conductivity was decreased. bp 2% had the greatest effect in reducing of K_s. This result could due to the higher water holding capacity of banana peel (Mohd Dom et al., 2021) that decrease movement of water so, the saturated hydraulic conductivity decreased compared with other amendments. Increase the application rate in all amendments significantly decreased the saturated hydraulic conductivity.

Pore water velocity

The pore water velocity is the average velocity of the water is the Darcy equation divided by the porosity $v = -Kh/n(\Delta h/\Delta L)$ where Kh is the saturated hydraulic conductivity, n is the porosity and is the hydraulic gradient. All amendments decrease pore water velocity. The highest effect was in bp 2% then poly 0.2% (Figure. 3). The results showed here are similar to those obtained from the effect on hydraulic conductivity. This was expected since pore water velocity is affected by both saturated hydraulic conductivity and saturated volumetric Water Content.

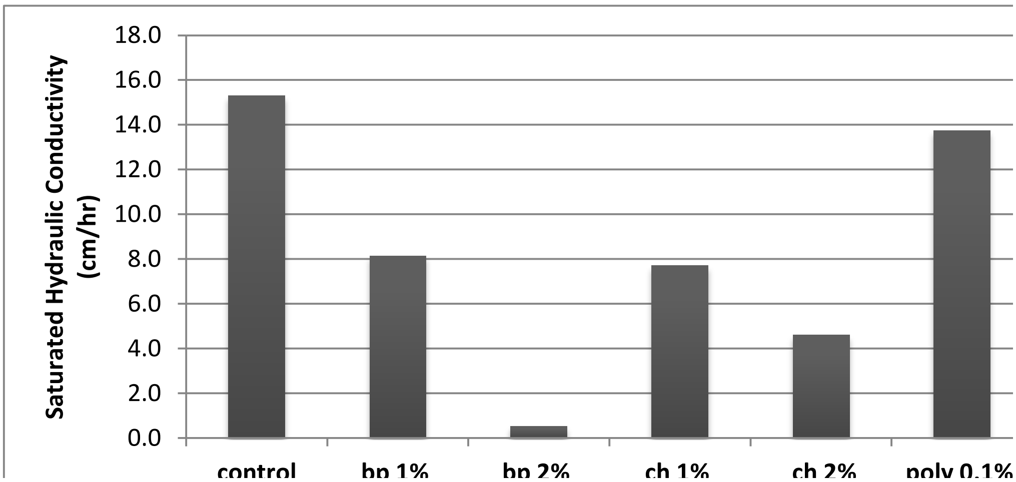

Fig.2. Effect of soil amendments on saturated hydraulic conductivity in soil column

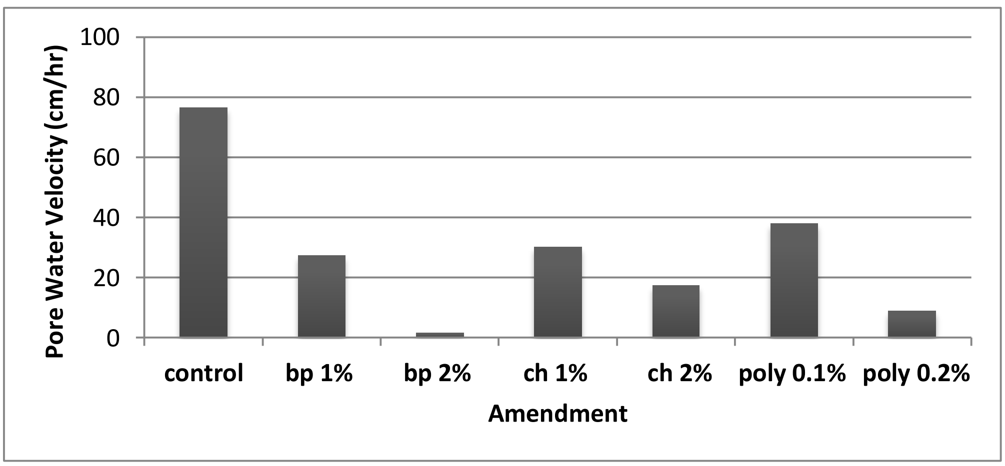

Fig. 3. Effect of soil amendments on pore water velocity in soil column

Measured breakthrough curves (BTCs) for chloride and potassium:

Chloride is an anion, so it does not absorb to soil particles and moves easily with water in the soil. Chloride has been commonly used as a non-reactive tracer (White and Broadley, 2001). Therefore, Cl^- movement within the soil is largely determined by the flow of water. A plot of the outflow concentration C/C_0 measured versus time volume is known as a solute breakthrough curve (BTCs). Figure 4 showed that Cl^- retardation factor is more than unity. It could be described by increase chloride retention in the upper layers of columns with aggregate size distribution in sandy soil reduced the contribution of transverse diffusion in large-sized aggregates as proposed by Amoozegar-Fard *et al.* (1983). From those BTCs it's clear that Chloride C/C_o reaches unity value in the effluent for the control before soil amendments. So, all amendments reduced water flow compared with control. Amendment bp 2% had the lowest pore water velocity and it observed that it takes longer for C/C_o to reach unity value. So, amendment of bp 2% is the best treatment to keep water and conserve it in sandy soil. Li et al., 2022. found the same results when the water velocity decreased; the time needed for the non-reactive solute to reach unity is increased.

Relative concentrations C/C_o for potassium vs. times are given in Figure (5). The pore water velocity effect on K^+ transport is similar to that observed in Cl^- transport. BTCs for Cl^- and K^+ in Figures 4,5, we noticed that the time which required for chloride to reach unity in all treatment is shorter than the time for potassium to reach such state.

Potassium is a reactive solute, and its transport depends on chemical reactions that might take place inside the soil column. bp 2% BTCs with the lowest pore water velocity exhibited a retardation in potassium movement comparison with other amendments. Potassium retarded related to decrease leaching (low pore water velocity) which meant that addition of amendments to soil reduce of leaching of nutrient and has an economical benefit and environmental impact.

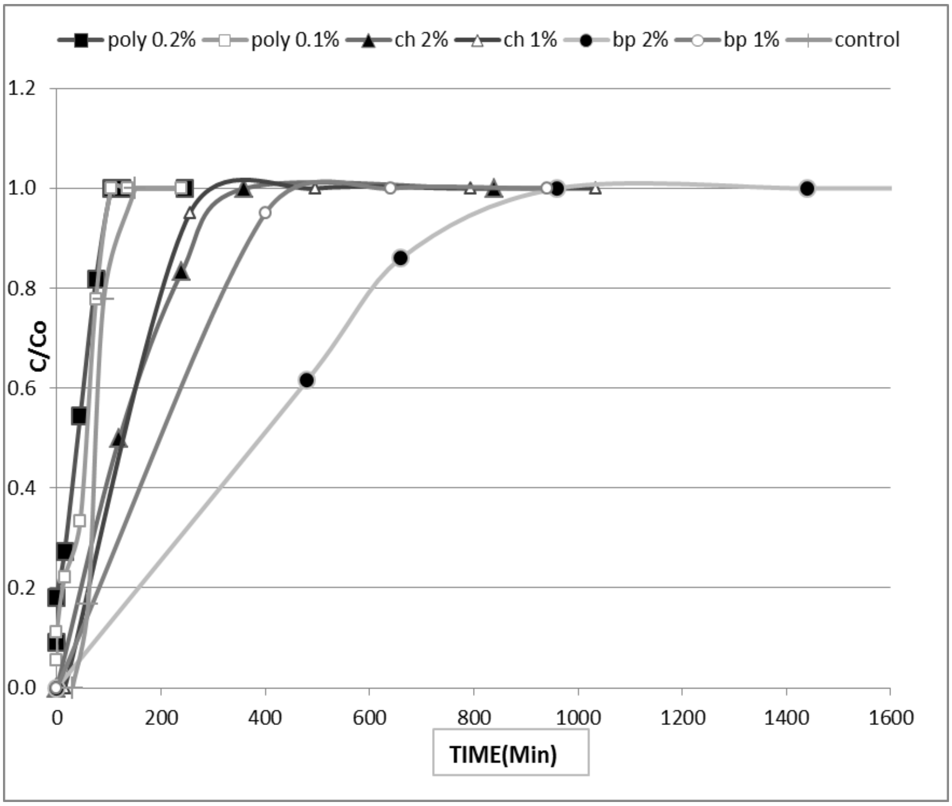

Fig. 4. Chloride BTC for soil columns C/C_o versus time

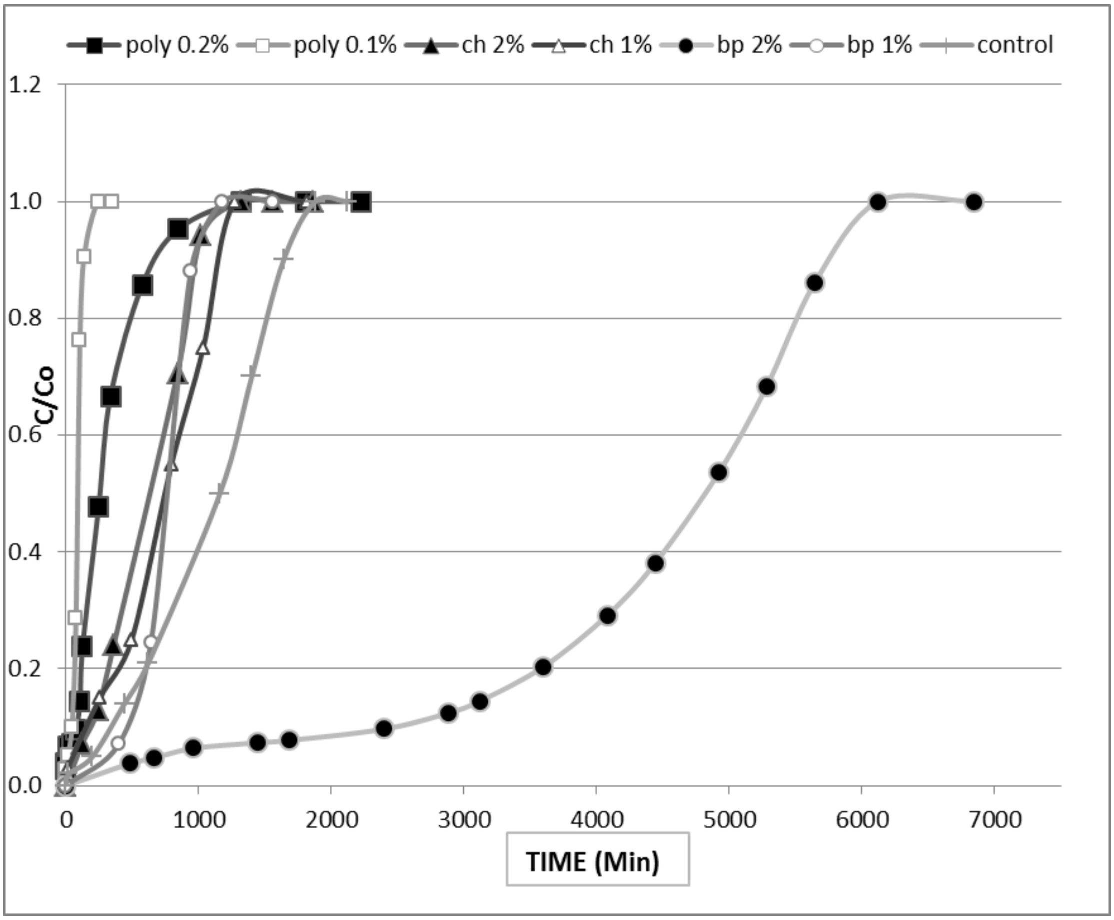

Fig. 5. Potassium BTCs for soil columns C/C_o versus time

CONCLUSION

Amendments are widely used to improve soil physical properties in sandy soil. Banana peel 2% mixture was the most effective in reducing hydraulic conductivity and pore volume velocity, polymer 0.2% comes second, adding 0.1% polymer did least improvement. Chitosan with both percentages did slight improvement on soil physical properties. Also bp 2% was the best amendment that increased potassium residence time in soil through decreasing pore water velocity and increase nutrient availability. It is recommended to add banana peels ground to improve soil properties and it is a good track for garbage management.

REFERENCES

Akhter, J., K.Mahmood, K.A.Malik, A.Mardan, M.Ahmad and M.M.Iqbal. 2004. Effects of hydrogel amendment on water storage of sandy loam and loam soils and seedling growth of barley, wheat and chickpea. *Plant Soil and Environment*. *50*(10): 463-469.

Amoozegar-Fard, A., A.W. Warrick and W.H.Fuller. 1983. A simplified model for solute movement through soils. *Soil Sci. Society of America J. 47*(5):1047-1049.

Azzam, R.A. 1980. Agricultural polymers polyacrylamide preparation, application and prospects in soil conditioning. *Communications in Soil Sci. and Plant Analysis*. *11*(8): 767-834.

Bai, W., H.Zhang, B.Liu, Y.Wu and J.Song. 2010. Effects of super-absorbent polymers on the physical and chemical properties of soil following different wetting and drying cycles. *Soil use and management*. *26*(3):253-260.

Black, C.A. 1965. Method of soil analysis part 2. *Chemical and microbiological properties*. *9*:1387-1388.

Buchholz, F.L. and A.T.Graham. 1998. Modern superabsorbent polymer technology. *John! Wiley & Sons, Inc, 605 Third Ave, New York, NY 10016, USA. 279*.

Chen, X., X. Mao, Q. Lu, Z. Liao and Z. He. 2016. Characteristics and mechanisms of acrylate polymer damage to maize seedlings. Ecotoxicology and Environmental Safety. 129:228–34.

Emami, H. and A.R. Astaraei. 2012. Effect of organic and inorganic amendments on parameters of water retention curve, bulk density and aggregate diameter of a saline-sodic soil. *J. of Agricultural Sci. and Technology*. *14*(7):1625-1636.

Gee, G.W. and J.W.Bauder. 1979. Particle size analysis by hydrometer: a simplified method for routine textural analysis and a sensitivity test of measurement parameters. *Soil Sci. Society of America J*. *43*(5):1004-1007.

Hassan, O. and T.Chang. 2017. Chitosan for eco-friendly control of plant disease. *Asian J. Plant Pathol*. *11*(2):53-70.

Johnson, M.S. 1984. The effects of gel-forming polyacrylamides on moisture storage in sandy soils. *J. of the Sci. of Food and Agriculture*. *35*(11):1196-1200.

Klute, A. and C.Dirksen. 1986. Hydraulic conductivity and diffusivity: Laboratory methods. *Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods*. *5*:687-734.

Li, Y., J.Bian, , Q. Wang and T. Li. 2022. Experiment and Simulation of Non-Reactive Solute Transport in Porous Media. *Groundwater*. *60*(3):330-343.

Liao, R., P. Yang, W. Wu and S. Ren. 2016. An inverse method to estimate the root water uptake source-sink term in soil water transport equation under the effect of superabsorbent polymer. Plos One. 11(8): e0159936.

Liao, R., W.Wu, S. Ren and P.Yang. 2016. Effects of superabsorbent polymers on the hydraulic parameters and water retention properties of soil. *J. of Nanomaterials*.

Martens, D.A. and Frankenberger W.T. Jr. 1992. Modification of Infiltration Rates in an Organic-Amended Irrigated. *Agronomy j*. *84*(4):707-717.

Mirzaei Aminiyan, M., A.A. Safari Sinegani and M.Sheklabadi. 2015. Aggregation stability and organic carbon fraction in a soil amended with some plant residues, nanozeolite, and natural zeolite. *International J. of Recycling of Organic Waste in Agriculture*. *4*(1):11-22.

Mohd Dom, Z., L.Mujianto, A.Azhar, S.Masaudin and R.Samsudin. 2021. Physicochemical properties of banana peel powder in functional food products. Food Research 5 (1): 209 – 215.

Reynolds, S.G. 1970. The gravimetric method of soil moisture determination Part IA study of equipment, and methodological problems. *J. of Hydrology*. *11*(3):258-273.

Saad, A.F. 2017. Influence of Organic Wastes on Evaporation and Hydraulic Properties of Sandy Soil. Alex. Sci. Exch. J. 38: 120-136.

Sheffield, J., E.F. Wood, M.Pan, H.Beck, G.Coccia, A.Serrat-Capdevila and K.Verbist. 2018. Satellite remote sensing for water resources management: Potential for supporting sustainable development in data-poor regions. *Water Resources Research*. *54*(12):9724-9758.

Sial, T.A., M.N.Khan, Z.Lan, F.Kumbhar, Z.Ying, J.Zhang, D.Sun and X.Li. 2019. Contrasting effects of banana peels waste and its biochar on greenhouse gas emissions and soil biochemical properties. *Process Safety and Environmental Protection*. *122*:366-377.

Sparks, D.L., A.L.Page, P.A. Helmke and R.H. Loeppert. 2020. *Methods of soil analysis, part 3: Chemical methods* (Vol. 14). John Wiley & Sons.

Tejada, M., J.L.Gonzalez, A.M. García-Martínez and J.Parrado. 2008. Application of a green manure and green manure composted with beet vinasse on soil restoration: Effects on soil properties. *Bioresource technology*. *99*(11):4949-4957.

White, P.J. and M.R.Broadley. 2001. Chloride in soils and its uptake and movement within the plant: a review. *Annals of botany*. *88*(6):967-988.

Yang, L., Y.Yang, Z.Chen, C.Guo and S.Li. 2014. Influence of super absorbent polymer on soil water retention, seed germination and plant survivals for rocky slopes eco-engineering. *Ecological Engineering*. *62*:27-3+2.

الملخص العربي

تأثير اضافة محسنات التربة لتحسين الخواص الهيدروليكية وحركة المذابات للتربة خشنة القوام

رشا محمد بدر الدين و سارة زقزوق

أجريت التجارب المعملية لمعرفة تأثير االمحسنات المختلفة على الخواص الهيدروليكية ونقل المادة المذابة في أعمدة التربة الرملية المشبعة. تم استخدام ثلاثة محسنات للتربة وهي قشر الموز المطحون والكيتوزان والبوليمر وجرعتان من كل تعديل تم دمجهما مع التربة بالإضافة إلى معاملة الكنترول (التربة فقط). تم خلط الكيتوزان (١٠ و ٢٠ جم كجم –١ تربة مجففة بالهواء) وقشر الموز المطحون (١٠ و ٢٠ جم/ كجم تربة مجففة بالهواء) وبوليمر أكريهوب (٠,١ و ٠,٢ جم / كجم تربة مجففة بالهواء) بشكل متجانس بالتربة ثم التعبأة في أعمدة PVC تحت حالة ثابتة مشبعة. تم وضع محلول K2SO4 + (0.01 N) CaCl2 (١٠٠ جزء في المليون من البوتاسيوم) على عمود التربة حتى وصل التركيز النسبي (C / Co) إلى الوحدة ، وتم جمع النفايات السائلة ثم تقدير تدفق الماء وقدرة التربة على الاحتفاظ بالماء وحركةالمغذيات. أظهرت النتائج أن جميع محسنات التربة أدت إلى زيادة المحتوى المائي للتربة، وانخفاض التوصيل الهيدروليكي المشبع (Kh) وانخفاض سرعة المياه المسامية (PWV) مقارنة بالكنترول. كان أفضل محسن هو مسحوق قشر الموز ٢٪ في تناقص Kh و PWV ، وبالتالي فإن التربة ستحتفظ بمزيد من الماء من قشور الموز ٢٪ وايضا كانت هي االمحسنات الفعالة التي زادت من توافر البوتاسيوم في التربة، من خلال اعاقة حركته. استخدام قشور الموز له العديد من المزايا مثل تعزيز خصائص التربة وهو وسيلة جيدة في إدارة النفايات. ونخلص إلى أن استخدام المحسنات في التربة الرملية لتحسين الخواص االهيرو ليكية للتربة وانتقال المغذيات مهم للغايه حيث تؤدي إضافة المحسنات للتربة إلى الحد من غسيل المغذيات كما لها فائدة اقتصادية وتأثير بيئي واعد.