Improving Light Textured Soil Properties by Water Regimes and Soil Amendments under Dry Land Conditions

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Abstract: A field experiment was carried-out at Agriculture Experimental Station of King Abdulaziz University (KAU), Hada Alsham, Saudi Arabia, to evaluate the changes in some physical and fertility properties of soil treated with humic acid and/or gel polymers in relation to those of untreated soil under two water regimes. Full irrigation level, (100% of required water) and minimum irrigation level (60% of full level). Under each irrigation level two soil amendments, humic acid with a rate of 10 kg ha^{-1} and gel Polymer with a rate of 16 kg ha^{-1} beside the control (not amended) were investigated. The experimental site was cultivated by barley for two growing Seasons using sprinkler system for irrigation. Results indicated that using soil amendments enhanced soil physical and fertility properties. They decreased soil bulk density and saturated hydraulic conductivity while increased water holding capacity, soil organic matter and soil nutrients under both irrigation level. The enhancement under minimum irrigation level was better that that of fully irrigation level. Ha treatment was better than Gp treatment. Therefore, using humic acid with a rate of 10 kg ha^{-1} with minimum irrigation is good option to enhance the important physical and fertility properties of light textured soils under dry land conditions.

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1.Introduction

Soil amendment compounds are materials added to soil to improve its physical and fertility properties, i.e., water retention, permeability, water infiltration, drainage, aeration, structure and nutrients availability. By this, a better environment for roots in addition to the plant growth is provided (Davies *et al.,* 2004).

Organic amendments like humic compounds can help to improve the soilstructure by increasing the amount of pore space and enhancing the air exchange, watermovement, water holding capacity and root growth. As a result, better drought resistance and reduction in water usage can be done. The contents of humic substance from plant nutrients act as organic fertilizers and are also energy sources for bacteria, fungi, and earthworms that live in the soil. Beside their contents from nutrients, humic substances can chelate soil nutrients consequently improve nutrient uptake, especially phosphorous, sulfur and nitrogen because they act as a storehouse of N, P, S, and Zn (Frank and Roeth, 1996; Davies *et al.,* 2004).

Superabsorbent polymers (SAP) are other types of soil amendments. They contain high amounts of functional groups enabling them to absorb large amounts of liquid and retain it. They are commonly sold at markets as water super absorbers with absorbing capabilities of 400-1500 g water per dry gram of hydrogel (Bowman and Evans, 1991; Akhter *et al.,* 2004; John, 2011).The main purpose of developing polymers is to improve the physical properties of poorly structured soils in areas subject to drought. The properties in view of researchers are increasing the water-holding capacity of soils, increasing water use efficiency, enhancing soil permeability and infiltration rates, reducing irrigation frequency, reducing compaction tendency, stopping erosion and water run-off, and increasing plant growth (Shanmuganathan and Oades, 1982; William and Gary, 1990; Shainberg and Levy 1994; Brandsma *et al.,* 1999; Ekebafe *et al.,*2011). Treating sandy soil with hydrophilic polymer enhanceswater-holding capacity to be like that retained in loamy soils (Hüttermann *et al.,*1999). The amendments of SAP contribute to delay permanent wilting points and to reduce drought stress on plants. They also support plant establishment and growth in dry soils (Abdel-Raouf and Mansour, 2003; Zeineldin and Aldakheel, 2006; Bhardwaj *et al.,*2007).

Method of application of super absorbent effects on plant growth. Sometimes spraying the hydrogels as dry granules or mixing them with the entire root zone is not effective. When hydogels are layered under a few inches below soil surface, the better results can be obtained. Although, interpreting the obtained results depend not only on the method of application but also on a number of factors has to be taken into consideration such as type of hydrogel, particle size, rate of application and type of plant (Flannery and Busscher 1982).

In Saudi Arabia, water resources are limited and the renewable recourses are very low, as a result, groundwater, which is the main source for water, has been severely exploited in the recent decades. Expanding agricultural area especially under dry condition with limited water resources is a great challenge facing researches now a day. Using soil amendments could be a good option for increasing water productivity and efficiency. Therefore, the objective of this study was to evaluate the changes in some physical and fertility properties of the soil treated with humic acid and/or gel polymers in relation to those of untreated soil.

2.Material and Methods

Location and experimental design

A field experiment was carried out during the growing seasons of 2012 and 2013 at the Agricultural experimental station of King Abdulaziz University located at Hada Alsham, 110 km north east of Jeddah (21° 48′ 3″ N, 39° 43′ 25″ E). The soil of the experimental site was classified as sandy loam with 0.78% organic matter. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot management and three replications. The main plots contain two irrigation treatments using sprinkler irrigation system. Two soil amendments beside the control were investigated in the sub-plot.

Treatments

Two irrigation levels were studied under the current research. Fully irrigated level (**I_{full}**) was 100 % of crop water requirementsand minimum irrigated level (**I_{min}**) was 60% of the first level. The interval between irrigation was every two days and every four days in I_{full} and I_{min} Respectively. Under each irrigation level two types of soil amendments beside the control (not amended soils) were added to the soil before the starting of each growing season for investigation. The amendment treatments were humic acid (Ha) with a rate of 10 kg ha^{-1} and gel-polymer (Gp) with a rate of 16 kg ha^{-1}. Both soil amendments were homogenously distributed on the soil surface, and then were mixed with the upper 15 cm of soil surface. The experimental soil was cultivated by barley for two growing Seasons. Normal culture practices required for barley cultivation were applied as recommended.

Soil sampling and measured parameters

After harvesting of each growing season, two undisturbed soil samples were collected from the upper 30 cm of soil surface for each plot with a soil core. The samples were used to measure soil bulk density, saturated hydraulic conductivity and water holding capacity. Another two disturbed soil samples were collected from each plot for each replicate to measure soil organic matter, Nitrogen, phosphorus and potassium.

Soil bulk density: was determined by the core method as explained in Blake and Hange. (1986).

Saturated Hydraulic Conductivity: was determined in the undisturbed soil samples and calculated according to the Darcy's equation (Klute, 1986) as follows:

$$Q = -K \frac{dH}{dZ}$$

Where:

Q = The water flux density, (cm min^{-1})

dH/dZ = he hydraulic potential gradient

K = Hydraulic conductivity of soil (cm min^{-1})

Water Holding capacity:

Soil water curves were determined by the pressure plate apparatus (Richards, 1948). Undisturbed soil samples were collected in steel rings 5 cm in diameter and then, saturated for 24h. The saturated samples were then subjected to matric potentials of-0.06, 0.1, 0.33, 0.66, 1, 2, and 3 bars. After equilibrium the retained moisture was calculated for each sample in each treatment.

Soil organic matter: was determined by titration as explained in Schumacher (2002)

N, P and K in soils: were measured as follows:

- *Total N* was determined according to the Kjeldahl method (Jackson, 1973) using Kjeltec auto 1030 analyzer.
- *Available P* was determined as described in Olsen (1982) using ammonium molybdate colorimetric methods.
- *Available K* was determined as described in Carson, (1980) using flame emission spectrophotometry.

Statistical analysis

Obtained data were analyzed using the statistical package software SAS (SAS Institute Inc., 2000, Cary, NC., USA). Comparisons between means were made by F-test and the least significant differences (LSD) at *P* = 5%.

3.Results

Soil bulk density (BD g cm^{-3})

The results of soil bulk density presented in table (1) revealed that, minimum irrigation level significantly decrease bulk density compared to fully irrigation level in both growing season. Amended treatments by either Ha or Gp were significantly decreased soil bulk density in comparison to control.

Treatments amended with Ha reduce soil bulk density more than Gp treatments, however the reduction was not significant. Results of the interaction of irrigation level and amendment treatments are presented in figure (1). Results indicated that, the least bulk density obtained from Ha treatment of minimum irrigation level and gradually increased in Gp and control respectively for both growing season, then followed by the same order in the fully irrigation level.

Table (1) Soil organic matter (OM), bulk density (BD) and saturated hydraulic conductivity (SHC) as affected by irrigation regimes and soil amendment treatments

Parameters	OM (%)		BD (g cm^{-3})		SHC (cm min^{-1}).	
	2012	2013	2012	2013	2012	2013
Water Regime (WR)						
I_{full}	1.24±0.11	1.45±0.13	1.57±0.04	1.58±0.03	0.153±0.016	0.151±0.01
$I_{minmum.}$	1.23±0.12	1.24±0.20	1.55±0.01	1.55±0.01	0.144±0.015	0.140±0.01
F-test	*NS*	*NS*	*	*	**	*
LSD (0.05)	-	-	0.014	0.013	0.004	0.005
Treatments (T)						
Humic Acid	1.65±0.03	1.95±0.05	1.55±0.01	1.54±0.01	0.125±0.0	0.121±0.0
Gel Polymer	1.08±0.04	1.28±0.04	1.56±0.01	1.55±0.01	0.140±0.0	0.140±0.0
Control	0.99±0.07	1.05±0.07	1.58±0.04	1.58±0.04	0.181±0.02	0.178±0.02
F-test	**	**	**	**	*	**
LSD (0.05)	0.066	0.07	0.017	0.02	0.001	0.003
Interaction (WR *T)						
F-test	*NS*	*NS*	**	**	**	**

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

Fig. (1) Effect of the interaction between irrigation level and soil amendment treatments on soil bulk density during the first (A) and the second (B) growing seasons

Saturated hydraulic conductivity (SHC, cm min^{-1})

Results of SHC were presented in table (1). Results showed that, the least SHC was measured in minimum irrigation level. Results also revealed a gradual significant decrease in SHC as affected by amendment treatments. The highest values recorded in control followed by Gp treatment while the least values were measured in Ha treatment. Results of the interaction presented in figure (2) showed that, the least SHC was found in Ha followed by Gp and control treatment of minimum irrigation level followed by the same trend in fully irrigation level for both growing seasons.

Fig. (2) Effect of the interaction between irrigation level and soil amendment treatments on saturated hydraulic conductivity (SHC) during the first (A) and the second (B) growing seasons

Soil organic matter percent (SOM %)

Soil organic matter percent was shown in table (1). Results of both growing season revealed that, SOM was insignificantly affected by irrigation levels. However, soil amendment treatments significantly increased SOM% in both growing season. The highest SOM % was found in Ha followed by Gp and Control treatments respectively. Moreover, SOM% was higher in second growing season than that of the first growing season. The interaction (irrigation level x soil amendments) was not significant (Table 1).

Water holding capacity

Results of water holding capacity are presented in figure (3). The results clearly indicated that fully irrigation level increased retained water in comparison to minimum irrigation level in both growing season. The retained water after the first growing season was highly increased especially under fully irrigation level by adding soil amendments. The highest retained water was measured in Ha followed by Gp treatment while the least amount of retained water was found in control treatment. Under minimum irrigation level the increase in retained water was measured under low soil water tension where the highest retained water found in Gp followed by Ha compared with control treatments. Under high soil water tension, the retained water was almost same in both soil amendment treatments. Results of the second season had the same trend as in the first one but the retained water was increased especially at high soil water tension (Fig. 3).

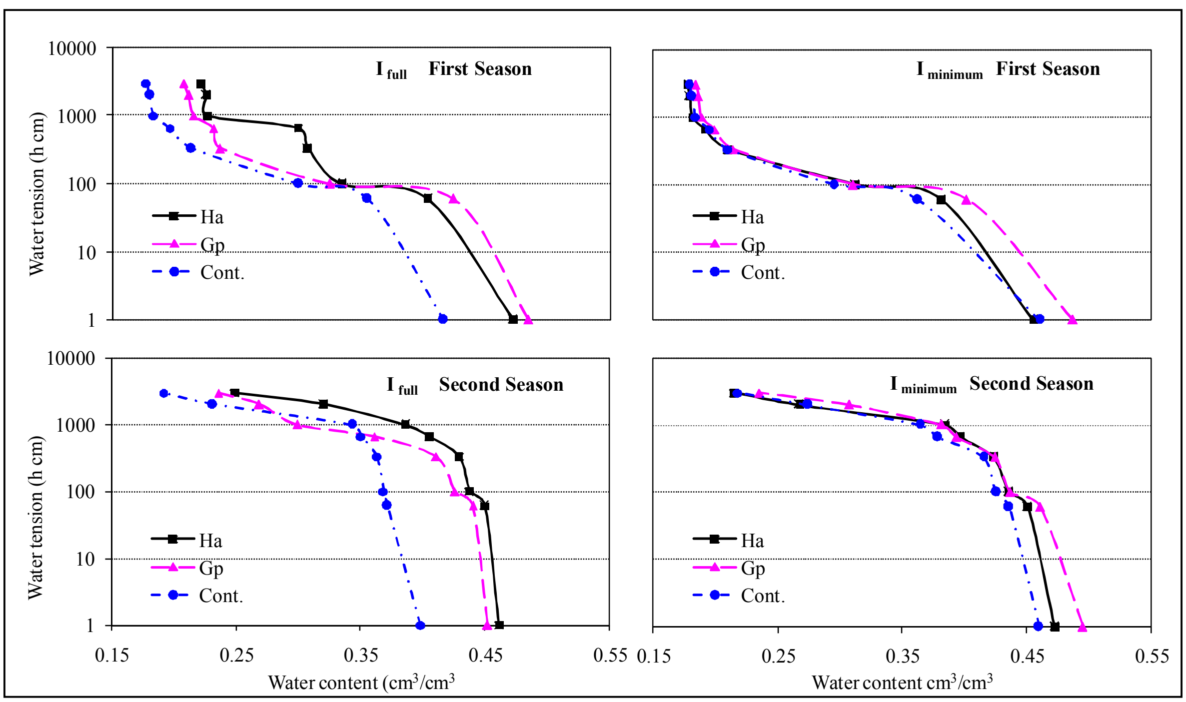

Fig. (3) Effect of irrigation levels and soil amendments treatments on retained water in sand

Nitrogen content (N%)

Results of soil N content is presented in table (2). The results indicated that soil N content was significantly decreased by increasing irrigation level where the highest N content was found in minimum irrigation level in both growing season. Soil amendment treatments increased N content in soil. The highest N content was obtained from Ha followed by Gp and control treatments respectively. Also N content of the second growing season was higher than that of the first season.

Table 2: N, P and , K, concentrations in soil as affected by irrigation regimes and soil amendment treatments

Parameters	N (%)		P (Mg/Kg)		K (%)	
	2012	2013	2012	2013	2012	2013
Water Regime (WR)						
I_{full}	0.66±0.06	0.73±0.12	58.8±2.9	63.3±6.5	0.045±0.005	0.048±0.003
$I_{minmum.}$	0.78±0.07	0.86±0.9	60.8±5.3	74.7±8.4	0.042±0.004	0.046±0.005
F-test	**	*	*NS*	*NS*	*NS*	*NS*
LSD (0.05)	0.091	0.112	-	-	-	-
Treatments (T)						
Humic Acid	0.95±0.03	1.04±0.03	68.6±6.2	72.8±6.6	0.046±0.005	0.050±0.00
Gel Polymer	0.67±0.07	0.73±0.08	56.1±4.8	73.8±7.9	0.045±0.005	0.050±0.00
Control	0.56±0.09	0.61±0.05	54.8±5.8	60.5±6.3	0.040±0.001	0.046±0.005
F-test	**	**	**	**	*	**
LSD (0.05)	0.016	0.019	5.9	6.88	0.004	0.0031
Interaction (WR *T)						
F-test	**	**	*NS*	*NS*	*NS*	*NS*

Means with the same letter within each column are not significantly different, (NS), not significant; (-), not calculated.

The results also showed significant differences for the interaction of irrigation level and amended treatments as presented in figure (4). Results clearly show that, the highest N content was obtained from Ha, Gp and control treatments of minimum irrigation level respectively, then followed by the same order in the full irrigation level.

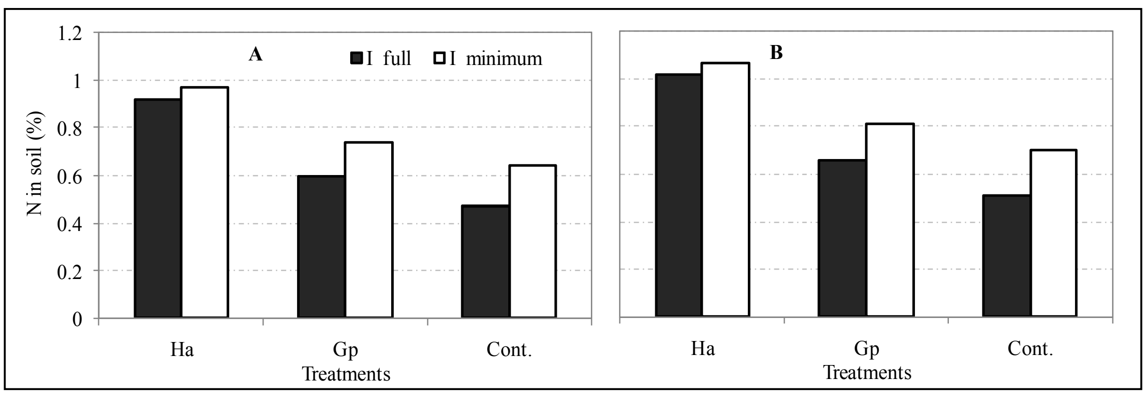

Fig. (4) Effect of the interaction between irrigation level and soil amendment treatments on N(%0 in soil after the first (A) and the second (B) growing seasons.

Phosphorus content (P *Mg/Kg*)

Irrigation levels had non-significant effects on soil P content (table 2). However, amendments treatment significantly increased soil P content. The highest soil P content was obtained from Ha treatments followed by Gp and control treatments at the first growing season, respectively. For the second growing season, soil P content of Ha and Gp was almost similar but significantly higher than that of control treatment.

Potassium content (K %)

Results of K content presented in table (2) indicated that, irrigation level had non-significant effects on soil K content. K contents of Ha and Gp amendment treatments was almost the same but significantly higher than that of control. Results also revealed that, the soil k content of the second season was higher than that of the first season.

4.Discussions

The reduction of soil bulk density in minimum irrigation level compared with fully one could be due to the low adsorbed water on soil particles. Low soil water content decrease the distance between soil particles and encourage granulation of light textured soils. As a result, soil volume was increased resulted in bulk density reduction. The reduction of bulk density as affected by soil amendments might be due to the enhancement of soil physical properties especially soil structure and aggregation, (Frank and Roeth, 1996; Davies *et al.,* 2004).

The reduction in soil bulk density directly reduced the saturated hydraulic conductivity as clearly indicated from the obtained results. The reduction could be attributed to the reduction in effective mean pore radius as a result of the soil expansion (Mustafa *et al.,*1988; Al-Darby *et al.,*1992).In additions, application of soil conditioners usually maintained and improved soil structure and decreasing soil erodibility (Brandsma *et al.,*1999).

The increase of soil organic matter (SOM) for amended treatments was superior for Ha treatment in both seasons followed by Gp and control. Humic acid is an organic substance so adding it to soil might increase soil organic matter (Chen *et al.,*1999 and 2001; Clapp *et al.,*2001). The increase of SOM could be also attributed to retained water in soil which encourages root proliferation intensively, resulting in large root biomass in soil and consequently high soil organic matter like in Gp treatments. However in control treatment low retained water resulted in low root biomass and low SOM, (Ismail and Ozawa, 2007).

Results of water holding capacity indicated that minimum irrigation level retained less water than fully irrigation level which is logic. Where the amount of water supply is lower than field capacity all supplied water is retained and increased by increasing water supply. Addition of soil conditioners like humic acid or gel-polymer increased the retained water. Increasing the retained water might be due to the enhancement in physical parameters of soil including increasing of soil aggregates, decreasing of bulk density, decreasing saturated hudraulic conductivity and increasing soil porosity (Shanmuganathan and Oades, 1982; William and Gary, 1990; Shainberg and Levy 1994; Brandsma *et al.,* 1999; Ekebafe *et al.,*2011). Hydrogels can absorb and retained more water as well as make it available to the plant. However, the water-holding capacity depends on the texture of the soil, the type of hydrogel and particle size (Flannery and Busscher 1982; Johnson 1984a). Results also showed that Gp treatment retained more water at low soil water tension compared with Ha and control. The behavior indicated that, at low soil water tension adhesion force between water Gp is higher than that of Ha. Results of second year clearly indicated that, soil amendments treatments increased adhesion and cohesion forces by retaining more water at high soil water potential.

Irrigation levels significantly decrease soil N% however P and K didn't affect. Increasing irrigation level as in fully irrigation reduce N content which is logic because N is always in dissolved form all the time and easily move down below the root zone with irrigation water. For amended treatments, Ha was the highest in both seasons especially in N% followed by Gp and control. Humic acid contains some nutrients in its structure and it is characterized by chelating soil nutrients. As a results, it improved nutrient uptake, especially phosphorous, sulfur and nitrogen and acts as a storehouse of N, P, S, and Zn (Frank and Roeth, 1996). Hydrogels are also claimed to increase soil NPK through interaction of the fertilizer with the polymer. They may also increase soil nutrients as a result of the reduction in leaching occurs due to their ability to retain the high amount of water (Flannery and Busscher, 1982).

Conclusion

The results of this research clearly indicated that using soil amendments enhanced soil physical properties. They decreased soil bulk density and saturated hydraulic conductivity while increased water holding capacity, soil organic matter and soil nutrients under both irrigation level. The enhancement under minimum irrigation level was better that that of fully irrigation level. Ha treatment was better than Gp treatment. In conclusion using humic acid with a rate of 10 kg ha^{-1} is recommended to use with minimum irrigation level to significantly enhance the important physical and fertility properties of light textured soils under dry land conditions.

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References

1 Abdel-Raouf, A., M.; S R. Mansour., 2003. Improving soil physical properties and its effect on acacia tortilisseedlings growth under field conditions. Asian Journal of Plant Sciences 2: 861-868, 2003

2 Akhter, J., Mahmood, K., Malik, K.A., Mardan, A., Ahmad, M., Iqbal, M.M. (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.

3 Al-Darby.A .M . ; V.Z. El-Shafei; A .A Shalaby ; M. Mursi,1992 Influence of gel forming conditioner on water retention, infiltration capacity and water distribution in uniform and stratified sandy soils. Arid Sci. Res 6:145 161

4 Bhardwaj, A.K., Shainberg, I., Goldstein, D., Warrington, D.N., Levy, G.J. (2007): Water retention and hydraulic conductivity of cross-linked polyacrylamides in sandy soils. Soil Science Society of American Journal, 71(2), 406-412.

5 Blake. G.R ; K.H. Hange. 1986. Bulk Density. P. 363-376. In. A. Klule (Ed.) Method of Soil Analysis, Part I 2nd Ed. Aeron Mongr 9 ASA and SSA. Madison, Wl,

6 Bowman, D.C., Evans, R.Y. (1991): Calcium inhibition of polyacrylamide gel hydration is partially reversible by potassium. HortScience, 26(8), 1063-1065.

7 Brandsma, R.T.; M.A. Fullen, ; T.J. Hocking. 1999. Soil conditioner effects on soil structure and erosion. J. Soil Water Conserv. 54: 485–489.

8 Carson, P. L., 1980. Recommended potassium test. pp. 12-13. In W. C. D Ahnke, (ed.). Recommended chemical soil test procedures for the North Central Region. North Central Region Publication 221 (revised). N. D. Agric. Exp. Stn., Fargo, N .D.

9 Chen, Y., Clapp, C.E., Magen, H. and Cline, V.W., 1999. Stimulation of Plant Growth by Humic Substances: Effects on Iron Availability. In: Ghabbour, E.A. and Davies, G. (eds.), Understanding Humic Substances: Advanced Methods, Properties and Applications. Royal Society of Chemistry, Cambridge, UK.. pp. 255-263.

10 Chen, Y., Magen, H., and Clapp, C.E., 2001. Plant Growth Stimulation by Humic Substances and Their Complexes with Iron. Proceedings of the International Fertilizer Society Symposium, Lisbon, March 2001

11 Clapp, C.E., 2001. An Organic Matter Trail: Polysaccharides to Waste Management to Nitrogen/Carbon to Humic Substances. In E.A. Ghabbour and G. Davies (eds.), Humic Substances: Structures, Models and Functions. Royal Society of Chemistry, Cambridge, UK.pp.3-17.

12 Davies, L.C., Novais, J.M., Martins-Dias, S. (2004): Detoxification of olive mill wastewater using superabsorbent polymers. Environmental Technology, 25, 89-100.

13 Ekebafe, L.O., Ogbeifun, D.E., Okieimen, F.E. (2011): Polymer applications in agriculture. Biokemistri, 23(2), 81-89.

14 Flannery, R.L. ; W.J. Busscher. 1982. Use of a synthetic polymer in potting soils to improve water holding capacity. Communications in Soil Science and Plant Analysis 13: 103 – 111

15 Frank, K.D. and Roeth, F.W., 1996. Using Soil Organic Matter to Help Make Fertilizer and Pesticide Recommendations. In: Soil Organic Matter: Analysis and Interpretation. Soil Science Society of America Special Publication No. 46, p. 33.

16 Hüttermann, A., Zommorodi, M., Reise, K. (1999): Addition of SAPs to prolong the survival of Pinushalepensis seedlings subjected to drought. Soil and Tillage Research, 50, 295-304.

17 Ismail SM, Ozawa K. 2007. Improvement of crop yield, soil moisture distribution and water use efficiency in sandy soils by clay application. App. Clay Sci, 37, 81-89.

18 Jackson, M. L. (1973). Soil Chemical Analysis.Prentice-Hall, Inc. Englewood Cliffs, N.J. New Delhi, India.

19 John, G.F. (2011): Towards improved application of super absorbent polymers in agriculture and hydrology: A cross-disciplinary approach. Master thesis of science.Graduate Faculty of Auburn University, Alabama.

20 Johnson, M.S. 1984a. The effects of gel-forming polyacrylamides on moisture storage in sandy soils. J. Sci. Food Agric. 35 : 1063 - 1066.

21 Klute, A (1986). Method of soil analysis.Part -1.physical and Mineralogical methods.2nd American Society of Agronomy, Madison, Wisconsin, U.S.A..

22 Mustafa. M A ; A M Al-Omran ; A .A Shalaby ; A.M. Al- Darhy 1988. Honzoraal infiltration of water in soil columns as affected by gel-forming conditioner Soil Set. 145:330¬336

23 Olsen, S. R, Sommers, L. E., 1982. Phosphorus. In: Page AL, *et al.* (Eds.), Methods of Soil Analysis, Part 2, 2 nd, AgronMonogr 9. ASA and ASSA, Madison WI, pp.403–430.

24 Richard. L.A 1948.Porous plate apparatus for measuring moisture retention and transmission by soil.Soil Sci. 60:105 110.

25 Schumacher, B. A. 2002. Methods for determination of total organic carbon (TOC) in soils and sediments. United States Environmental Protection Agency Environmental Sciences Division National Exposure Research Laboratory P.O. Box 93478 Las Vegas,NV 89193-3478

26 Shainberg, I. ; G.J. Levy. 1994. Organic polymers and soil sealing in cultivated soils. Soil Sci. 158, 267–273

27 Shanmuganathan, R.T. ; J.M. Oades. 1982. Effect of dispersible clay on the physical properties of the B horizon of a red-brown earth. Aust. J. Soil Res. 20, 315–324.

28 William, J.F., Gary, J.K. (1990): Water absorption of hydrophylic polymers (hydrogels) reduced by media amendments. Journal of Environmental Horticulture, 8(3), 113-114.

29 Zeineldin, F.I., Aldakheel, Y.Y. (2006): Hydrogel polymer effects on available water capacity and percolation of sandy soils at Al-Hassa, CSBE/SCGAB Annual Conference, Edmonton, Canada.

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