Misr J. Ag. Eng., 28(2): 324 - 335

POTENTIAL USE OF POLYACRYLAMIDE FOR IMPROVING AVAILABILITY OF SOIL MOISTURE AND PLANT PRODUCTION IN SANDY SOIL

F. A. Gomaa* and F. M. Romian**

ABSTRACT

Two pot experiments were carried out under greenhouse conditions to examine the effect of applied forms (granular , soluble in water) and additive percentages (0.01 , 0.02 , and 0.03 % by weight) of Polyacrylamide (P A M) to light-textured soil in order to changing soil water behavior and plant production .The obtained results showed that the addition of polyacrylamide to sandy soil under different levels and forms of application reduced evaporation from the soil surface .The results showed a low rate of water evaporation with values ranged between 11.62% and 19.3% of control under both treatments of (PAM) in granular, and soluble forms at 0.03% addition level, respectively and thus increased the water stored in the soil. The addition of polyacrylamide raised the moisture content at saturation (0.001 bars) and field capacity (0.33 bar) compared to the control and the differences increased with increasing PAM concentration, especially under soluble form. All levels and forms of PAM had no clear effect on the retention of water in the soil at wilting point(15 bar).Available water that ranged between 0.33 bar and 15 bar increased 1.92 times of control under the less influential treatment (soluble, 0.01%) and to 3.12 times under the highest impact treatment (soluble, 0.03%).Under all treatments the fresh and dry weights of (Eruca Sativa) plants increased compared with the control treatment. The results indicated that the dry weight increased 1.49 times the control under the highest impact treatment (soluble, 0.03%).Water use efficiency increased under all treatments compared to the control, especially at high levels of PAM at both forms. The results indicated a more water use efficiency than the control under levels of application 0.03% for both forms. These results may indicate that PAM can enhance rates of nutrient absorption and improve the growing conditions of plant roots.

Keywords: Soil conditioner; water holding capacity; available water

***Soil Dept., Fac. Agric., Cairo Univ. Egypt**
****Plant production Dept., Fac.Agric.,Qassim Univ. Saudi Arabia**

INTRODUCTION

Sandy soils have some major problems such as low fertility, inadequate water retention, wind erosion, water erosion, drought and loss of irrigation water and plant nutrients. However, it could be as productive as any fertile soil, if the right soil water management practices are followed. Adding clays or organic manures and composts to sandy soil were practiced to keep moisture more available in such soils. Frequent water application and use of synthesized soil conditioners are another agricultural practices to save water in sandy soils. Although clays (100 to 150 m^3/acre) could be mixed with sand to improve its water retentivity, such treatment is expensive and labor. It is usually justified only when land is very limited. the application of organic materials to sandy soil (10 to 20 ton / acre) , has quite a similar effect to that of clay with some exceptions that organic matter is usually decomposed too fast that it is difficult to maintain more than 1 or 2 percent without heavy and seasonal manuring , ***(El–Hady et al., 2003***). The use of synthesized conditioners, to perform a suitable environment for planting sandy soils, has become an acceptable practice. Among these conditioners are hydro gels that associate quickly with irrigation water to form gels. These conditioners can increase sandy soils capacity to retain water that is available to plants for some considerable time .Also that improve the structure of sandy soil as well as soil porosity. Both chemical and biological properties of the conditioned soils are also improved. Moreover, germination process, plant growth, nutrient uptake, yield and both water and fertilizers use efficiency by plant were beneficially increased, ***(Ouchi et al. 1996; Nus 1992; Smagin and Sadovnkova 1995; Nadler et al. 1996; El-Hady et al. 2001; El-Hady et al. 2002; El-Hady et al. 2003; Mamedove et al. 2007; Annabi et al. 2007; Petreson et al. 2007; Lepore et al. 2009***) .

The aim of the present work is to studying the effect of Polyacrylamide additive to sandy soil on the water use efficiency and plant production under greenhouse conditions.

MATERIALS AND METHODS

Two pot *experiments* were carried out *under* greenhouse conditions on a virgin sandy soil. The sample of sandy soil was air-dried and passed through a 2-mm sieve, and treated with Polyacrylamide in two forms (granular , soluble in water), and three application rates (0.01 % , 0.02 % , and 0.03% w/w) with three replicates for each treatment .The used soil conditioner PAM has the following properties (granular , non-ionic [-CH2CH(CONH2) -] n , density = 750 kg/m³ , and average M.W.5 to 6.0 00.000). Some physical and chemical properties of soil and irrigated water determined (according to ***klute et al. 1986)*** are shown in Table (1).

Table(1) :The physical and chemical properties of soil and irrigated water

Soil sample:	
Texture	sand (USDA) (2% clay,3% silt,95% sand)
Bulk density	1600 kg/m^3
Total porosity	27.77 % (w/w)
Organic matter	0.1%
ECe (1:1 extract)	0.92 ds/m
pH	7.86
SAR	0.72 meq/l
CaCO3	1%
Irrigation water:	
ECe	1.38 ds/m
pH	7.18
SAR	6.62 meq/l

<u>The first experiment</u> (without cultivation):

This trail was carried out to study the effects of forms and application rates of PAM on the water evaporation via the free soil surface by weighing the pots each other day to calculate the amount of evaporation, taking in mind the amount of drainage water. To achieve this experiment, each pot was filled with 3.7kg soil/pot and packed to a bulk density 1600 kg/m³ and total porosity 27.77% w/w. The pots were saturated with water then evaporation rate was calculated by weighing the pots each other day during 14 days of irrigation (this experiment was repeated for three cycle of irrigation).

Sub samples from each treatment were saturated for 24 h on the pressure plate. These samples were used to obtain the soil water retention relationships for matric suction corresponding to saturation, field capacity, and wilting point ***(klute et al 1986).***

The second experiment:

The pots which have the same properties like the first experiment were cultivated with *Eruca sativa* as a plant indicator.

The plants didn't expose to water stress during the growth by repeating irrigation to keep the soil moisture content close to field capacity and the excess water was collected to calculate the water consumptive use and water use efficiency for all treatment.

After 45 day the fresh and dry weight, as well as water use efficiency were calculated for different treatments.

RESULTS AND DISCUSSION

1- Evaporation from soil surface

Data illustrated in Table (2) and Figure (1) showed that, the polyacrylamid treatments reduced the amount of water evaporated from the free soil surface. This reduction may be attributed to effect of this polymer on the contact angle in the interface between soil particles and water hence decreased the velocity of capillary rise of water in soil micro pores and consequently reduced rate of evaporation.

Table (2): Effect of PAM treatments on total evaporation %.

Treatment	Total evaporation (%)	Significant differences
control	88.97	88.97 a
PAM. Granular	-	-
0.01%	85.9	85.90 ab
0.02%	84.18	84.18 bc
0.03%	77.35	77.35 d
PAM. Soluble	-	-
0.01%	81.51	81.51 c
0.02%	80.6	80.60 cd
0.03%	69.67	69.67 e

Means with the same letters are not significantly different

Recorded data showed also that there were differences between the treatments (forms & rates of PAM application). The soluble form reduced the rate of evaporation more than the granular form may be due to the good mix and distribution with soil particles. As the application rate increased the evaporation rate decreased under the two forms of application .The statistical analysis indicated that there were significant differences between the treatments and the control at significant level of 0.05%.The reduction of evaporation ranged between (3.45–21.69%) of control according to different treatments .The highest rate of evaporation reduction was found at the application rate of 0.03% for both soluble or granular forms. The reduction at 0.03% treatment was 13.06% and 21.69% for granular and soluble application forms, respectively. The obtained data for second and third irrigation cycles nearly showed the same trend of the first cycle. As the evaporation reduction increased the water storage increased.

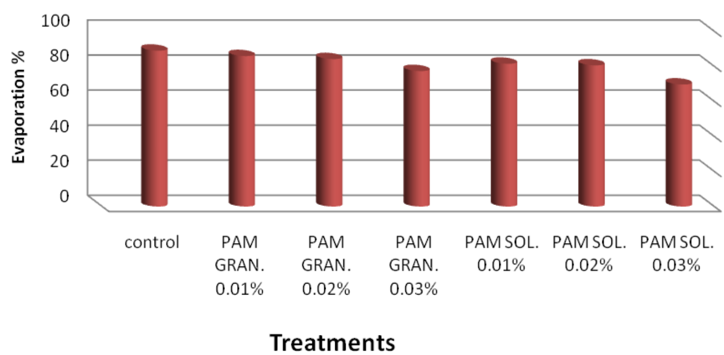

Fig. (1): The total evaporation under different treatments

2-Soil moisture availability:

Data in Table (3) and figure (2) showed clearly that mixing polyacrylamid with soil caused considerable increases in soil moisture content at field capacity, and available moisture content .Meanwhile there was no effect on soil moisture content at wilting point under all treatments. Moreover, the magnitude of excess water was more pronounced upon increasing the concentration of (PAM), especially under soluble application form as compared with control. The moisture retention at field capacity (determined at 0.33 bars) were 1.81, 2.20, and 2.46 times more than the control upon using 0.01%, 0.02%, and 0.03%

granular polyacrylamid, respectively. Similarly, the moisture retention at field capacity were 1.82, 2.53 , and 2.9 times more than the control, upon using 0.01%, 0.02%, and 0.03% soluble polyacrylamid, respectively. Concerning the soil moisture retention at permanent wilting point (15 bars), the data indicated that treating sandy soil with polyacrylamid in both forms did not affect soil moisture content significantly. It was evident that mixing the soil with hydrophilic conditioner lead to increasing the amount of available water under all treatments as compared with control. The values of available water content were 1.95, 2.37, and 2.67 times more than the control upon using 0.01%, 0.02%, and 0.03% granular poly acryl amid respectively while were 1.92, 2.74, and 3.12 times more than control upon using 0.01, 0.02, and 0.03 % soluble poly acrylamid respectively. The best effect for adding PAM recorded at the highest level of addition under both addition forms. As available water content increased the irrigation interval can be increased and the total amount of irrigation water decreased.

Table (3): Volumetric soil moisture contents at saturation, Field capacity, Wilting point, and available water contents as affected by PAM treatments

Treatment	**Retained moisture content (Ɵv%) against the applied pressure (bar)**			**Available water content %**
	Saturation	**Field capacity**	**Wilting point**	
	0.001 bar	**0.3 bar**	**15 bar**	
control	37.94	7.04	0.84	6.2
PAM. granular				
0.01%	38.96	12.78	0.69	12.09
0.02%	39.68	15.53	0.82	14.71
0.03%	39.18	17.36	0.76	16.60
PAM. soluble				
0.01%	45.91	12.86	0.93	11.93
0.02%	45.18	17.84	0.84	17.00
0.03%	47.62	20.45	1.08	19.37

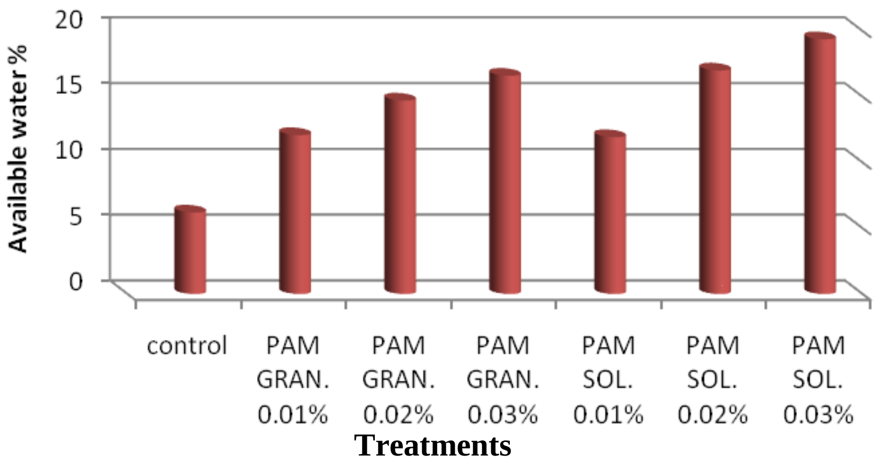

Fig. (2): Available water content under different treatments

3-Evaluation of fresh and dry weight of the plant:

Soil conditioners are not fertilizers as such, but influence plant growth indirectly through there effect on soil physical improvement. The data stated in Table (4) and illustrated in figure (3) indicated that, all PAM treatments increased plants fresh weight as compared with control. The increasing percentage of fresh weight for all treatments comparing to control ranged between (2.38 and 14%). There were differences in fresh weight between the treatments, although they received approximately the same amount of irrigation water and there differences in fresh weight ranged between 960 – 1069 Kg/acre. The higher fresh weight was conducted under the rate of application 0.03% of soluble polyacrylamid, and the lower fresh weight was conducted under rate of application 0.01% of granular polyacrylamid .Also, the data explained that the effect of soil conditioner on dry weight was obvious specially under 0.03% application rate for the granular and soluble application which reached to 161.21 and 175.5 Kg/ac respectively. The increasing percentage of dry weight under different treatments ranged between (7.85 – 49.56 %) comparing to control. Application of soil conditioners resulted in a marked increase in dry weight.

4- Water use efficiency (WUE).

The water use efficiency for each treatment was given in Table (3). The ranking of the treatments in the order of increasing yield and (WUE) were as follows: control < PAM granular 0.01 % < PAM granular 0.02% < PAM granular 0.03% /or PAM soluble 0.01%, 0.02% < PAM soluble 0.03%. Statistical analysis showed that there were some differences within and between the treatments and control. The best treatments were recorded at 0.03% application rate for both granular and soluble PAM, these treatments caused an increase of about 35.41% and about 47.91% with respect to control respectively.

Table (4): Fresh, Dry weight, Water use efficiency, and analysis of variance for Water use efficiency

Treatment	Mean fresh weight Kg/ac	Mean dry weight Kg/ac	Water consumptive use m^3/ac	Water use efficiency Kg/m^3	WUE* Analyses variance
Control	**937.7**	**117.34**	**60.90**	**1.92**	**1.93 e**
PAM granular					
0.01%	960.2	126.53	61.34	2.06	2.06 d e
0.02%	1049.99	135.71	61.76	2.23	2.24 d
0.03%	1065.300	161.21	60.83	2.60	2.61 b c
PAM. soluble					
0.01%	1024.48	155.10	61.45	2.52	2.52 c
0.02%	1036.73	158.16	61.62	2.57	2.57 c
0.03%	1069.00	175.50	61.74	2.84	2.84 a b

Means with the same letters are not significantly different

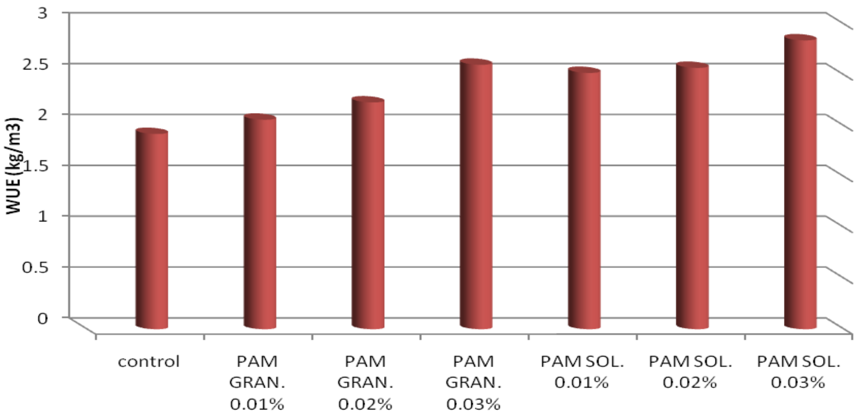

Fig. (3): Water use efficiency under different treatments

CONCLUSION

In conclusion, the addition of (PAM) to sandy soil under different application rates (0.01% , 0.02% , and 0.03% w/w) and different forms (granular & soluble) decreased the total evaporation percent, especially under application rate of 0.03% for both forms of application (granular and soluble) which ranged between 11.62% , 19.3% as compared with control, respectively .Analysis of variances showed some significant differences in total evaporation percent between treatments at 0.05% level of significance .Soil moisture content at saturation (0.001 bar), and field capacity (0.33 bar) increased under all treatments especially under application rate of 0.03% for the soluble form. However, there were no effects for the different treatments on soil water retention at wilting point (15 bar) but the available water content increased. The available water content increased by about 1.92 and 3.12 times comparing with control under the lowest treatment (0.01% , granular) and the highest treatment (0.03 % soluble).The fresh and dry weight increased under all treatments comparing with control, especially under 0.03% application rate for the soluble form . These results may indicate the benefit of PAM in improving the plant uptake and root growth conditions. The dry weight increased 1.49 times the control for the 0.03% application rate in the soluble form .Water use efficiency increased by 1.35 and 1.48 times the control under 0.03% application rate for both forms, respectively.

Therefore this study may recommend that the best rate of (PAM) is 0.03% for both forms.

In general, the wide use of gel-conditioners (PAM) in the field is currently limited by the cost, especially with high rates. However, it might be recommended to add the conditioner to the soil area adjacent to the root of trees and to plant (cash crops) grown in greenhouses.

Acknowledgment

Authors are grateful to Saudi Arabia Basic industries Corporation (SABC) for providing financial support for carrying out this work.

REFERENCES

Annabi, M., S. Houot, C. Francou, M. Poitrenaud and Y. Le Bissonnais. 2007. Soil aggregate stability improvement with urban composts of different maturities. Soil Sci. Soc. Am. J. 71:413–423.

El-Hady, O. A., B. M. Abd El-hady, N. A. Rizk and E. L. El-Saify. 2003. The potentiality for improving plant- soil – water relation in sandy soils using some synthesized Am-Na (ork) ATEA hydrogels. Egypt.J. soil Sci., 43(4):215-229.

El-Hady, O. A., A. A. Abdel_Kader and N. M. Badran. 2001. Forage yield, nutrients uptake and water and fertilizers use efficiency by ryegrass (Lolium multiforum, L.) grown on a sondy calcareous soil treated with acrylamid hydrogels or/and manures. j. Agric. Sci. Mansoura Univ., 26(6):3465-3481.

El-Hady, O. A., S. M. Adam and A. A. Abdel_Kader. 2002. Sand-compost-Hydrogel mix for low cost production of tomato seedlings. Egypt .J.Soil Sci., 42(4):767-7282.

Klute, A. et al (Editors) . 1986. Methods of soil analysis part 1 and 2 , and edn American socity of Agronomy Medison,WI.

Lepore, B. J., A. M. Thompson and A. Petersen. 2009. Impact of polyacrylamide delivery method with lime or gypsum for soil and nutrient stabilization. Journal of Soil and Water Conservation, May 1, 2009; 64(3): 223 - 231.

Mamedov, A. I., S. Beckmann, C. Huang, and G. J. Levy.2007. Aggregate stability as affected by polyacrylamide molecular weight, Soil texture, and water quality. Soil Sci. Soc. Am. J., October 29, 2007; 71(6): 1909 - 1918.

Nadler, A., E. Peffect and B. D. Key. 1996. Effect of polyarylamide application on the stability of dry and wet aggregates. Soil Sci. Soc. Am.J, 60:555-561.

Nus, J. E. 1992. Water absorbing polymers. Golf course Management. June 1992.26-40.

Ouchi, S., A. Nishikawa and E. kamada. 1990. Soil improving effects of a super-water-absorbent polymer (part2). Evaporation, leaching of salts and growth of vegetables. Jap. Jour. Soil Sci. plant Nutrition , 61(6): 606-613.

Petersen A., A. M. Thompson, C. Baxter, J. Norman, A. Roa-Espinosa. 2007. A new polyacrylamide (PAM) formulation for reducing erosion and phosphorus loss in rainfed agriculture. Transactions of the ASABE 50(6):2091-2101.

Smagin, A. V. and N. B. Sadovnikova. 1995. Impact strongly welling hydrogels on water-holding capacity of light-textured soils . Eurasian Soil Sci., 27 (12): 26-34.

الملخص العربى

أمكانية استخدام البولي اكريلاميد في تحسين صلاحية الماء الارضى ونمو النبات في الأرض الرملية

فتحي عبد الحليم جمعة*　　　　فهد محمد الرميان**

هدفت الدراسة الي تقييم أثر إضافة البولي اكريل أميد الي التربة الرملية على كفاءة الاستخدام المائي ونمو نبات (الجرجير) تحت ظروف الصوب .
وقد أجريت هذه الدراسة بإضافة البولي اكريل أميد إلى التربة الرملية بثلاث مستويات مختلفة هي (٠,٠١% ، ٠,٠٢% ، ٠,٠٣%) من وزن التربة وبصورتي إضافة مختلفتين (محببة ، صورة ذائبة في مياه الري) بهدف دراسة تحسين صلاحية الماء الأرضي وأثر ذلك على إنتاجية نبات الجرجير (كمؤشر نباتي) .

* قسم الأراضي والمياه - كلية الزراعة – جامعة القاهرة.
** كلية الزراعة والطب البيطري – قسم إنتاج النبات ووقايته – جامعة القصيم .

وقد اوضحت نتائج الدراسة أن:

- إضافة البولي اكريلاميد إلى التربة الرملية تحت مستويات وصور الإضافة المختلفة أدت إلي تقليل البخر من سطح التربة بقيم تتراوح بين ١١,٦٢% ، ١٩,٣% عن معاملة الكنترول وذلك تحت معاملتي إضافة (PAM) على صورة محببة وصورة ذائبة عند مستوى إضافة ٠,٠٣% لكل منهما على التوالي .
- وجود اختلافات معنوية عند مستوى ٥% بين المعاملات المختلفة مقارنة بمعاملة الكنترول .
- إضافة البولي اكريل أميد يعمل على رفع نسب المحتوى الرطوبي عند كل من التشبع (٠,٠١ بار)، والسعة الحقلية للتربة (٠,٣٣ بار) مقارنة بمعاملة الكنترول ويزداد الفرق بزيادة نسب الاضافه خصوصا تحت صورة الإضافات الذائبة عنه في حالة الإضافة في صورة محببة . ومن ناحية أخرى فقط وجد أن كل من مستويات الإضافة وصورة الاضافه لم يكن لها تأثير واضح على استبقاء الماء داخل التربة عند نقطة الذبول إلا أن الهدف النهائي للاضافه هي رفع كمية الماء الميسر للنبات بدرجات واضحة خصوصا عند مستويات الإضافة العالية ٠.٠٣% لكل من صورتي الإضافة (محببة ، ذائبة) .
- تراوحت زيادة كمية الماء الميسر بين ١,٩٢ مرة قدر معاملة الكنترول وذلك في اقل معاملات الإضافة تأثيرا (صورة ذائبة ، ٠,٠١%) حتى وصلت إلى ٣,١٢ مرة قدر معاملة الكنترول وذلك تحت أعلى معاملات الإضافة تأثيرا (صورة ذائبة، ٠,٠٣%)
- زاد الوزن الرطب والوزن الجاف لكل معاملة مقارنة بمعامله الكنترول وان كان هناك زيادة واضحة بزيادة مستويات إضافة (PAM) على الصورة الذائبة وهذا يشير إلى تحسن معدلات امتصاص العناصر الغذائية وظروف نمو جذور النبات عند الإضافات المختلفة للبولي اكريلاأميد.
- زيادة الوزن الجاف بمقدار ١,٤٩ مرة قدر معامله الكنترول تحت مستوى إضافة ٠,٠٣% على الصورة الذائبة .
- زيادة كفاءة استخدام المياه تحت كل المعاملات مقارنة بمعاملة الكنترول خصوصاً تحت مستويات الإضافة المرتفعة لكل من صورتي الإضافة حيث تشير النتائج إلى زيادة كفاءة الاستخدام بمقدار ١,٣٥ ، ١,٤٨ مرة قدر معاملة الكنترول تحت مستويات إضافة ٠,٠٣% لكل من الصورة المحببة والذائبة على التوالي .