Effect on the Absorption Rate of Agricultural Super Absorbent Polymers under the Mixer of Soil and Different Quality of Irrigation Water

Rajiv Dabhi[1]
P.G. Student, Department of Civil Engineering, L. E. College, Morvi, Gujarat, India

Neelkanth Bhatt[2]
Assistant Professor, Department of Civil Engineering, Govt. Engineering College, Rajkot, Gujarat, India

Bipin Pandit[3]
Professor and Head Civil Engineering Department, L. E. College, Morvi, Gujarat, India

Abstract

The objective of this experimental study was to evaluate water absorption rate of agricultural Super Absorbent Polymers (SAP, Polymers or Hydrogels) under the mixer of soil and water of different quality for irrigation, and to calculate the quantity of SAP material required for optimizing the water use efficiency. It was found that the absorption rate of SAP gradually decreased as the Total Soluble Solids (TSS) of the irrigation water increased. Moreover, it was also found that the rate of water absorption by the SAP was reduced by 27 %-59% when it was amended under soil water mixture. Consequently, it was inferred that the dosages of SAP in the agricultural soil amendments cannot be standardized as it varies according to the characteristics of the soil. SAP is not suggested for the soils with high permeability and less water holding capacity.
Key words: Super Absorbent Polymers, Water Absorption, Soil Water Mixture, Total Soluble Solids (TSS), Soil Permeability, Soil Water Holding Capacity

1. Introduction

Super-absorbent polymers (SAP, Hydrogel, Polymers) a new water-saving materials and soil conditioners, have been widely adopted in agriculture in the advanced countries of the world. SAP materials are hydrophilic networks that can absorb and retain huge amounts of water [1]. Research evidences suggest that when the soil is treated with SAP, the water volumetric content of the soil increases significantly and as the soil dries, the stored water is released back slowly into soil. Further, fertigation is also possible by the application of SAP to the soil as the same is capable of absorbing the fertilizer and releasing the same with water. It was also noted by Amjad Asri Abed Altarawneh in 2012 that the water holding capacity (WHC) did increase by 143% and that the permanent wilting point was delayed by 9 days [2]. Soil moisture can be increased by 6.2–32.8% with SAP application [3]. Relative water content (RWC), Water Use Efficiency (WUE) and irrigation intervals also can be increased by application of super absorbent polymer [4], [5]. SAP has a significant effect on plant height and percentage of soil moisture after being harvested [6]. When the SAP is mixed with the soil it can increase grain yield [7], [8]. Water evaporation rate is decreased after the addition of SAP in the soil, it works like a sub-miniature reservoir to retain and supply moisture to crops over time as the soil under-went alternate wetting and drying periods [9]. Repeated water absorbencies in tap water, mixture of distilled water and soil, and mixture of tap water and soil were reduced by 73.4–99.3% relative to those in distilled water. Moreover, water quality had a greater effect on original water absorbency than soil extractions. Water absorbency increased with SAP's concentration, and such increase was reduced with repeated utilization [10]. Super-absorbent polymers have the potential to remove water from porous media (soil structure) [11]. After SAPs were mixed in the soil, their capacity of absorbing and desorbing water showed a downward trend with time and outside water condition [12].

There are very little known facts about the performance of SAP and the effect of soil on the rate of water absorption by the SAP under different types of soil and different quality of water. This experimental study was therefore carried out to evaluate the rate of water absorption by the SAP under different quality of water and under the influence of soil.

2. Material and Methods

The experiment was conducted at the Government Polytechnic, Jamnagar (Gujarat State, India). Aqua-reserve [13] makes agricultural SAP (average particle size 1.5mm). Soil sample from the agricultural field was classified as silt-clay-loam (as > 56% material passed through ISS Sieve No. 200), Screens – 2 no. (ISS Sieve No. 14 and ISS Sieve No. 240), Transparent solid plastic container of 500ml - 8 no, Transparent glass beakers of 500ml – 8 no., Digital scales [14] ranging 0.01 to 200 grams were used for the precise measurement of absorbance rate by SAP in water and mixtures of soil and water of different qualities. Water samples were collected from various resources of the Jamnagar (Gujarat, India) City and its surroundings. Its quality was analyzed in the laboratory and the results are presented in table 1

2.1 Water absorbency measurement of SAP in water.

Each glass beakers were primarily filled with 250ml water samples of different qualities. 0.20 grams SAP particles were kept under full saturation up to 90 minutes. Absorbed SAP particles were separated from the soil from each container by screening the water absorbed SAP through ISS Sieve No. 240. Retained SAP particles were measured precisely and absorption rate were calculated.

2.2 Water absorbency measurement of SAP in the mixture of soil and water of different quality.

Agricultural Soil was screened through ISS Sieve No.14 adequate perforations were made in the bottom of each plastic container to drain of the excess water as to make prototype field condition. Filter paper is put on the bottom of each container to eliminate soil and SAP particles by draining of from the container. Each container is primarily filled with the 250ml of sieved soil by volume. As SAP can absorb huge amount of water in the experiment 0.20 grams SAP particles were mixed with the soil thoroughly in dry state in the container as to give optimum chance to absorb water from the mixture of soil and water, of different quality. Each container is topped up with different qualities of water samples. Though, almost 80% absorption occurs within initial 20 minutes time [15], containers were kept undisturbed for 90 minutes to have 100% saturation of SAP. Immersed SAP particles were separated from the soil from each container by washing the soil water mixture through 2.44mm sieve. Retained SAP particles were measured precisely and the results were drawn.

2.3 Calculations

The water absorbency of SAP in the water and in the mixture of soil and water of different quality is calculated according to following equation: W (grams) = (SAPS grams – SAPD grams) / SAPD grams. Where, W is grams of water per gram of dry SAP (g/g), SAPS and SAPD is the saturated and dry weight of SAP particles.

Table – 1. Results of irrigation water quality test

Sr.	Source of Water	Nomenclature	TSS (PPM)
1	Rain Water	SW1	154
2	Domestic RO Plant water	SW2	158
3	Tap Water (Domestic water, Reservoir water)	SW3	390
4	Bore-well Water, Valkeshwari Nagari, Phase-2	SW4	989
5	Hand Pump, Kadiyawad	SW5	1206
6	Bore-well Water, Valkeshwari Nagari, Phase-1	SW6	1374
7	Bore-well Water, Rameshwar nagar	SW7	2647
8	Sea Water, Bedi Port, Jamnagar	SW8	11710

3. Results and discussion

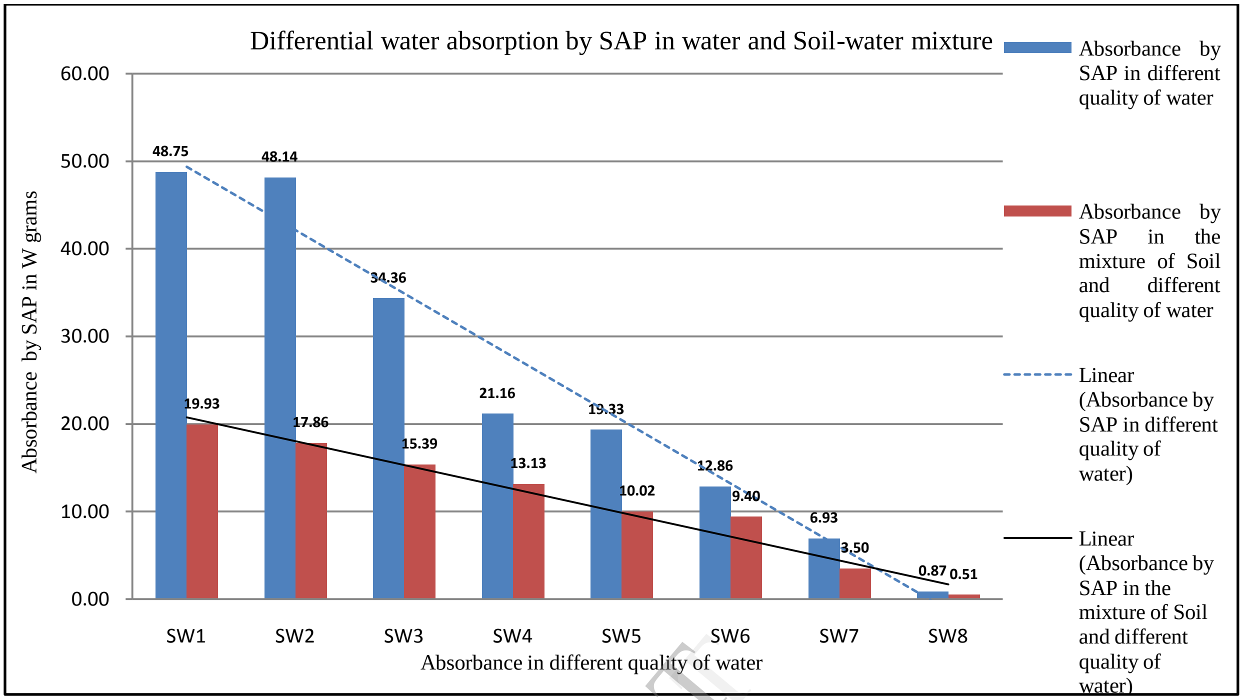

Chart – 1, Water absorption by SAP in different qualities of water and soil water mixture

SW1 and SW2 were significantly absorbed by the SAP (240 times of dry SAP weight). With a small increase in TSS, the absorbency of SW3 by the SAP was decreased (170 times of dry SAP weight). Further increase in TSS in SW4 and SW5 it was observed that the rate of water absorption decreased considerably (105 to 95 times of dry SAP weight respectively). Even higher value of TSS had significant impact on the rate of water absorption by the SAP. The rate of water absorption by SAP under the influence of SW6 and SW7 was lower by 65 to 35 times of the dry SAP weight. Furthermore, SAP had negligible absorption in SW8 as it had extreme level of TSS value. Trend line in the Chart - 1 shows linear reduction in the absorption rate by SAP with the increase of TSS.

Above findings cannot be singlehanded utilized to estimate the quantity of SAP material required for the soil amendments to enhance soil moisture retention capacity; as the above findings would only stands when SAP are fully submerged only under water up to its full saturation for prolonged duration. While in the field, near the plant root zone it is not feasible to keep water reservoir (water logging condition) as it adversely affect the plant root [15] hence water is made available by the soil water mixture from which SAP has to absorb water and is to be kept under reservation and releases when the soil in the surrounding of SAP gets dried out.

Drawing no. 1 mentions functioning of SAP in the field. Experimental results of the absorbance rate by SAP under mixture of soil and water of different quality have given striking alteration in the absorption behavior of the SAP. Reduction in the water absorption by SAP was observed between 27% to 59% in mixtures of soil and water of different quality as compared to the water absorption by SAP observed entirely in water. In actual field condition SAP particles does not get ample opportunity and time to acquire absorption equivalent as it is entirely under water. In the field condition SAP particle is surrounded by the soil water mixture moreover water is continuously under draining condition where root zone is not affected by the ground water table. Soils by its nature retain water in their soil pores. Water holding capacity of soil largely depends upon average particle size and shape, particle size distribution, minerals, organic matter, various chemical compounds and soil air. In addition to these basic components, soil usually contains numerous living organisms such as bacteria, microorganisms, insects, protozoa, algae and small animals which directly or indirectly affect the soil structure [15]. Permeability and water retention capacity of various soil textures are mentioned in the table no. 3.

Table - 2 Permeability and water retention of various soil textures [16]

Soil Texture	Permeability	Water Retention
Sand	High	Low
Loam	Medium	Medium
Silt	Low	High
Clay	Low	High

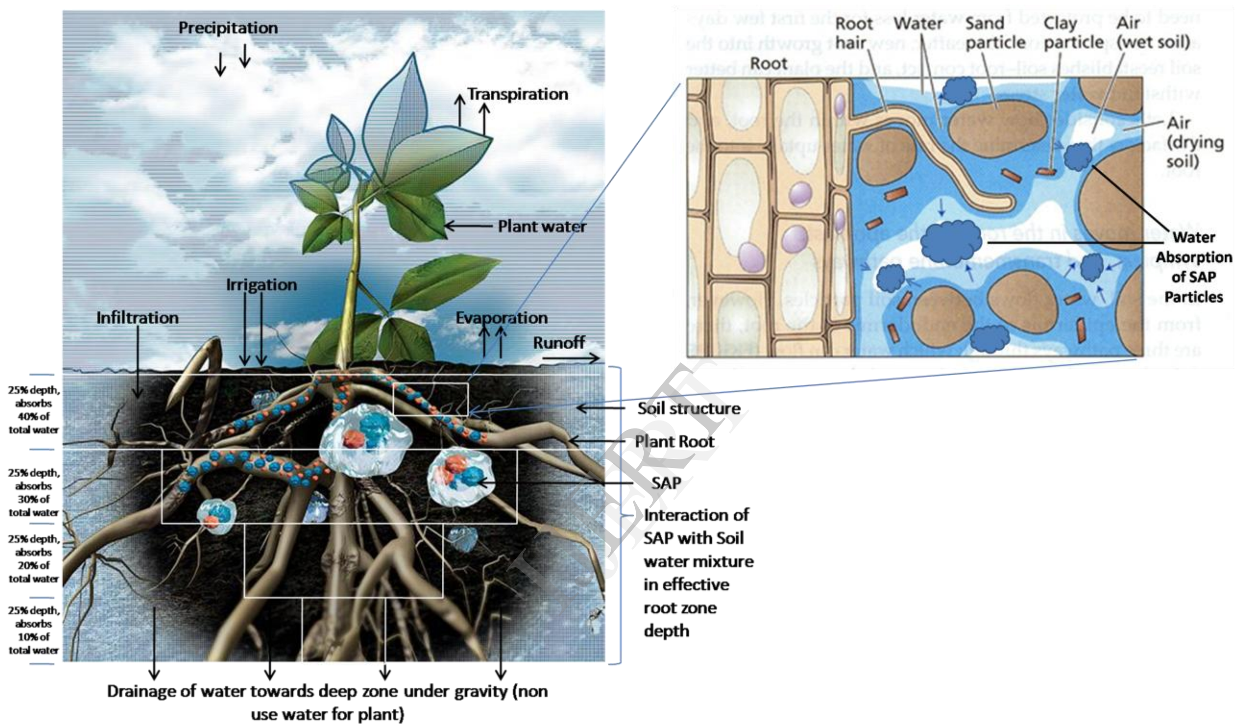

Figure 1 - Schematic sketch showing functioning of SAP near root zone under Soil water mixture (Reproduced using published under reference [18, 19])

SAP can be beneficially employed if it can retain higher volume of water by its own dry weight as to increase water holding capacity of soil when it is conditioned with SAP particles. Absorption rate of SAP is dependent mostly on two factors viz. quality of irrigation water, and properties of the irrigation soil. As it is experimentally proven that SAP can be used economically when irrigation is either rain fed or conducted with the water of surface storage reservoir [17], hence the subsequent effective factor is the soil property. Soils with higher permeability and low water retention (sandy soils) give less time to SAP particles to absorb water. Loam has medium state of permeability and water retention hence SAP particles gets average opportunity to absorb water from the soil water mixture. Silt and clay have lower permeability and higher water retention hence higher absorbance rate can be achieved. Furthermore 80% absorbance by SAP is arising within initial 20 minutes of submergence in water [17], hence in view of lower absorbency in soil water mixture between 27% to 59%, the required contact period of SAP particles would be 26 minutes to 32 minutes under soil water mixture to absorb water in optimum quantity. Contact period varies according to the characteristics of soil. It would not be possible to retain soil moisture, without draining off the water from the soil structure, for such a longer duration.

4. Conclusion

Absorption rate of SAP is greatly reduced when it is emended with the mixture of soil and water. While SAP is used as a soil conditioner to enhance water holding capacity of the soil, quality of water to be used for the irrigation and properties of the soil shall be the governing factors that ought to be considered. SAP is strongly suggested for use in silty and clayey soils. SAP is not recommended with quick draining soils (desert sands and coarse grained soils). SAP can only absorbs water when it is fully surrounded by soil water mixtures hence soil amended with SAP if watered through drip or sprinkler type irrigation methods shall not be applicable.

5. References

[1] Mohammad J. Zohuriaan-Mehr and Kourosh Kabiri, Iranian Polymer Journal, 17 (6), 2008, pp.451-477[2] Amjad Asri Abed Altarawneh, Impact of Soil Amended Superabsorbent Polymers on the Efficiency of Irrigation Measures in Jordanian Agriculture, Dissertation, The 4th International Congress Eurosoil, Bari, Italy, 2-6 July, 2012
[3] W. Bai, H. Zhang, B. Liu, Y. Wu & J. Song, Effects of super-absorbent polymers on the physical and chemical properties of soil following different wetting and drying cycles, Soil Use and Management, 26, September 2010, pp.253–26
[4] Leila Keshavars, Hasan Farahbakhsh, Pooran Golkar, The Effects of Drought Stress and Super Absorbent Polymer on Morphphysiological Traits of Pear millet (Pennisetum glaucum), International Research Journal of Applied and Basic Sciences. Vol. 3(1), 2012, pp.148-154
[5] Parinaz pouresmaeil, Davood Habibi, Masoud Mashadi Akbar Boojar, Mohsen Tarighaleslami and Sepand Khoshouei, Effects of superabsorbent application on Agronomic characters of red bean (Phaseolus vulgaris L.) cultivars under Drought stress conditions, International Journal of Agriculture and Crop Sciences. IJACS/4/24/2012, pp.1874-1877
[6] Sayed Aminollah Agashiry, Khodabakhsh Panahi Kordlaghari, Hossein Pouzesh and Ali Rahimi, Effects of Super- absorbent and Different Levels of Potassium Sulphate on Soil Moisture and morphological Features of Rain-fed Wheat in BoyerAhmad Region, Iran, Scholars Research Library, Annals of Biological Research, 3 (6): , 2012, pp.2781-2784
[7]Seyed Hashem Khadem, Mohammad Javad Rousta, Mustafa Chorom, Seyed Ali Khadem and Ali Kasraeyan, The effects of different rates of super absorbent polymers and manure on corn nutrient uptake, 19th World Congress of Soil Science, Soil Solutions for a Changing World 1, Brisbane, Australia, 6 August 2010, pp. 314-316
[8] Zahra Moslemi, Davood Habibi, Ahmad Asgharzadeh, Mohammad Reza Ardakani, Abdollah Mohammadi and Azam Sakari, Effects of Super Absorbent Polymer and Plant Growth Promoting Rhizobacteria on Yield and Yield Components of Maize under Drought Stress and Normal Conditions, American-Eurasian J. Agric. & Environ. Sci., 12 (3): 2012, pp.358-364
[9] Falu Zhan, Mingzhu Liu, Mingyu Guo, Lan Wu, Preparation of Superabsorbent Polymer with Slow-Release Phosphate Fertilizer, State Key Laboratory of Applied Organic Chemistry, College of Chemistry and Chemical Engineering,Lanzhou University, Lanzhou 730000, People's Republic of China, 14 January 2004, pp. 3417-3421
[10] Wenbo Bai, Jiqing Song & Huanzhong Zhang, Repeated water absorbency of super-absorbent polymers in agricultural field applications: a simulation study, Acta Agriculturae Scandinavica, Section B - Soil & Plant Science ,Volume 63, Issue 5, 2013, pp. 433-441
[11] M. Oostrom, K.V. Smoot, T.W. Wietsma, M.J. Truex, M.D. Benecke and G.B. Chronister, Vadose Zone Soil Moisture Wicking Using Super-Absorbent Polymers, 2012, Vol. 11 No. 4
[12] Yuguo Han, Xinxiao Yu, Peiling Yang, Bo Li, Lei Xu and Chengzhi Wang, Dynamic study on water diffusivity of soil with super-absorbent polymer application, Environ Earth Sci 69: 2013, pp.289–296
[13] Aqua-reserve (experimental SAP material)
Website: http://www.auqreserve.com/
[14] Digital scales,
Website: http://www.scalesgalore.com/ppocket.htm
[15] Michael A. M., Irrigation Theory and Practice, Second Edition, Vikas Publishing House Pvt. Ltd., 2008, pp. 423-664
[16] J.G. Davis and C.R. Wilson, Choosing a Soil Amendment, Colorado State University, Fact Sheet no. 7.235
[17] Rajiv Dabhi et al., Effect of Irrigation Water Quality on the Rate of Water Absorption by Super Absorbent Polymers, International Journal of Emerging Technology and Advance Engineering, Vol.3, Issue.11, 2013, pp.496-500
[18] Website: www.tankonyvtar.hu
[19] Website: www.popsci.com