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Biodegradable Nano-Hydrogels in Agricultural Farming - Alternative Source For Water Resources

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Abstract

The desertification and lack of water are serious problems in many parts of the world because of compromise agriculture farming. Desertification is the degradation of land in arid, semiarid and dry areas resulting from various factors including climatic variations, but primarily human activities. The solution of this problem is by the use of synthetic materials with good water absorption and retention capacities under high pressure or temperature. Systems of this type are the Super Absorbent Polymers (SAPs). Due to their excellent properties, these SAPs were already well established in various applications such as disposable diapers, hygienic napkins, cement, drug delivery systems, sensors, and agriculture. The most essential components of these applications are water absorbency and water retention. The present research work is aimed to establish biodegradable Nano-polymers for sustainable agricultural farming.

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Keywords: Nanopolymers; Biodegradation; Superabsorbent polymers; Water retention; water absorbency; Silver nano-composite.

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1.0. Introduction

Nanotechnology is the modern technology used in agriculture. The yield of crop production in dry land areas is mainly influenced by variation in amount and distribution of rainfall. 70 percent of 143 million hectare of total

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cultivated area in the country is rain fed. The dry land areas supplies 42 percent of the total food grain production of the country. The most critical factor of failure in yielding the second crop after the rice production is soil moisture. According to the report of Hayat and Ali in (2004), the restrictive factor for crop production in arid and semi-arid regions is Moisture Stress due to low and uncertain. Super Absorbent Materials are hydrophilic polymer complexes which have capacity to absorb large volume of aqueous fluids within short period of time and desorb the absorbed water under stress condition. According to Bowman and Evans, (1991); Woodhouse and Johnson, (1991), Super absorbent polymer holds 400-1500 g of water per dry gram of hydrogel. Johnson and Veltkamo, (1985) have suggested that when these hydrogel are used correctly, 95% of their stored water is available for plant absorption. Polymers are classed into three categories by Woodhouse and Johnson (1991): starch-polyacrylonitrile graft polymers (starch co-polymers), vinyl alcohol-acrylic acid co-polymers (polyvinyl alcohols) and acrylamide sodium acrylate co-polymers (cross-linked polyacrylamides). They are called as super absorbents which hold up to thousand times of their existing weight of water (James and Richards, 1986). When these absorbents are mixed with the soil, an amorphous gelatinous mass is formed on hydration. They are capable of cyclical absorption and desorption for long period of time. Hence these absorbents act as a slow-release source of water and dissolved nutrients in the soil. The survival of seedlings is enlarged by increasing the time of wilting between intervals of rainfall and may lead to increased yields in certain conditions. The drought stress effects can be reduced by the application of super absorbent polymer and improves plant yield and agriculture production stability (Khadem*et al*., 2010 and Ali *et al.,* 2014). In the connection with the above survey, the present study is focused on the water holding capacity, water absorbency and water retention capacity of a calcium coated nano clay composite cross-linked polyacrylamides.

1.1. Material And Methods

The Silver coated nano-clay composite cross-linked polyacrylamides polymers were developed in the Department of Biotechnology, Acharya Nagarjuna University, Nagarjunanagar and Guru Nanak Institute of Technology, Ibrahimpatnam R.R. Dist, Telangana during 2009-14. Silver coated hydrogels were synthesized by polymerization reaction with 8% acrylic acid, 1-5% acrylamide, 0.9% ammonium persulphate as initiator, 0.12% N, N-methyl bis-crylate as cross linker loaded with 10% clay at 65°C reaction temperature in presence of nitrogen gas. Before polymerization reaction 10% of Silver nitrate was added for the formation of Silver–coated SAP. The dried polymerized sample was further crushed in a heavy wooden mortar and made into a fine powder. This product was tested for water sorption properties for agriculture purpose.

Table 1.

S.No.	Hydrogel	Silver nitrate (g)	Clay (g)	Water (ml)	Typeof clay
1	Nbp-1	9.8	0.2	250	Red clay
2	Nbp-2	9.7	0.3	250	Black clay
3	Nbp-3	9.8	0.2	125	Sand clay
4	Nbp-4	9.5	0.5	125	Mixed clay
5	Nbp-5	9.8	0.2	250	Black clay

6	Nbp-6	9.8	0.2	125	Red clay
7	Nbp-7	9.6	0.4	250	Black clay
8	Nbp-8	9.6	0.4	125	Red clay
9	Nbp-9	9.8	0.2	250	Black clay
10	Nbp-10	9.8	0.2	125	Red clay
11	Nbp-11	9.6	0.4	250	Black clay
12	Nbp-12	9.6	0.4	125	-
13	Nbp-13	9.8	-	250	-
14	Nbp-14	9.8	-	125	-

1.2. Modification of Hydrogel

Nanostructured clay is used in three forms: as a powder, aqueous suspension and in jelly-consistence. Encapsulation is carried out as follows: Silver nitrate is added to the water at 65°C under stirring, subsequently the clay is added and finally, after perfect homogenization, 1 g of dry hydrogel is added. It is allowed to stand for 10 minutes to produce solid SAP and filtered by using a Buchner funnel. The filter cake is transferred to a china dish for drying. This procedure is repeated with number of samples coated with different composition of mixture.

1.3. Determination of Degree of Swelling:

250 mg of prepared Super Absorbent Polymer is transferred to a glass beaker containing 250 to 300 ml of distilled water or 50 ml of 0.9 wt% NaCl solution and allowed to stand to examine the degree of swelling of the polymer. After the polymer attains the equilibrium-swelling state, it is filtered with the help of 30µm filter cloth or a paper filter and is weighed. The degree of swelling is then calculated from the ratio of weighed-out sample to weighed-in sample in g/g. Each determination is carried out three times with ±5% of accuracy. The product that is prepared in accordance with Nbp-1, a degree of swelling results is obtained as 300 g/g in distilled water and 47 g/g in 0.9% NaCl solution.

1.4. Determination of the pH value

The pH value of the product obtained in accordance with Nbp-1 is 6.5 in 0.9% NaClsolution.

1.5. Determination of the Water-Soluble Portion (WSP)

0.5 g of the swollen superabsorbent polymer is taken in a beaker containing 500 ml of de-ionized water and stirred for 16 hours at 20°C. After filtration of the gel, the WSP is obtained from the determination of the solid content obtained from the filtrate. The WSP value amounts to 5.9 wt. % in the case of the product obtained.

2. Results And Discussion

2.0. Characterization of SAP using Scanning Electron Microscopy (SEM)

The SEM images of the SAPs are given in fig: 1 the pore size increases with increase in acrylamide content. The quantity of pores decreases with increase in acrylamide in the polymer. The pores in the polymers are formed when ethanol evaporates from the polymer during the drying process. The difference in pore size and quantity is caused by the cross-linking density. Acrylamide increases cross-linking density and forms a tight network structure in the polymer. In the preparation process, when ethanol vaporizes from the polymer system, required pressure has to be created to break the tight polymer structure. The SAP requires more vapors to create enough pressure to break the tight network structure. Keeping in view of soil moisture retention and micronutrient requirement, a novel poly (acrylamide-co-acrylic acid)/silver coated superabsorbent hydrogel nano-composite is synthesized for agricultural use. SEM analysis of the synthesized nanoparticles is carried out and the results are shown in Fig 1. The SEM analysis shows that nanoparticles have a mean diameter of 200nm also reported by Liu et al., (2008) in his experiments of polysaccharide nano composites size reported by Sachiko Kaihara Nitta and KeijiNumata (2013). The Scanning Electron Micrograph of silver coated hydrogels also shows the particle size to be around 200 nm. Bajpaiet al., (2014) reported similar results in SEM studies of nanocomposites homogeneous morphology with irregular pores of 5 to 1000 µm diameter are visible at low magnification. But SCB fibres CH flakes with 5 to 500 µm length are visible on the surface of nanocomposite at lower magnification. SCB and CH were coated with PAA or PAAm appeared as bright areas and the dark areas represented fuller's earth with 4000 magnification no pores were visible, which suggested that CH and SCB were completely embedded in the polymeric matrix intercalated within FE.

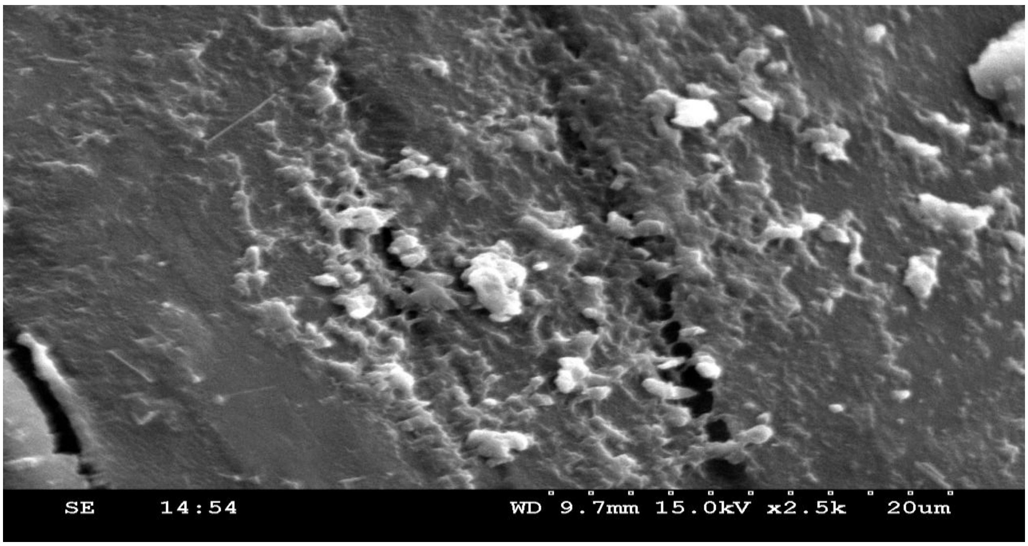

Figure-1: SEM analysis of biodegradable super absorbent nanoclay 20µm

2.1. Water Absorption of silver coated hydrogels

The water absorbency rate of Silver coated hydrogel is observed high in distilled and tap water compared to 1% NaCl solution (Fig. 2). The swelling and shrinkage behavior of the developed silver coated hydrogels are greatly influenced by the characteristics of external solution such as charge valencies and salt concentration. The maximum quantity of water absorbed by Silver coated-SAP is 190 g/g for distilled water, 161 g/g for tap water and 119 g/g for saline water during its 1st hydration cycle (Fig. 3). The absorption of water by Silver coated hydrogels is thus found to be faster in distilled water compared to tap and saline water, and the maximum absorption is achieved in 25, 68 and 92 h. in distilled, tap and saline water respectively. Swelling of polymer in the case of saline water is less due to difference in osmotic pressure. The increase in osmotic pressure of the external solution and concentration of the NaCl solution.Kayalvizhy in the year 2014 synthesized and characterized the nanocomposite and reported that the swelling rate always depends on the duration of time determined by the diffusion mechanism. This leads to the reduction of the difference in osmotic pressure between internal and external of superabsorbent, which reduces the swelling rate and capacity. Akhtar et al., (2004) reported as the water uptake by hydrogels synthesized from a mixture of N, N-methylene-bis-acrylamide, Na and K salts of acrylic acid. However, the maximum water uptake was 505 g/g in distilled water followed by 212 g/g by tap water and 140 g/g by saline water during the first hydration cycle.

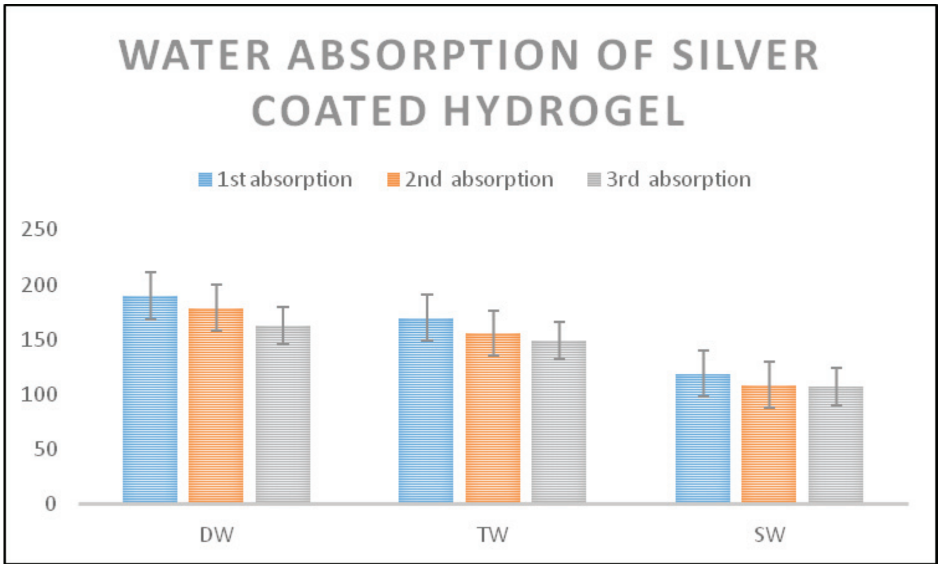

Figure 2: Water absorption of Silver Coated Hydrogel

2.2 Water-holding capacity of the soil

The experiment results indicated that the water-holding ratio of the soil with silver coated hydrogel and soil with hydrogel was 7.5% and 3.5% higher respectively, when compared to original soil. This shows that the silver coated hydrogel has excellent water absorbency in soil, and improves the water holding capacity and water use efficiency of the soil. The silver coated hydrogels resourcefully store rainwater or irrigation water to 130 to 190 times of its weight. This is one of the significant advantages over the conventional coated slow-release fertilizers.

2.3 Water-retention behavior of silver coated hydrogel in soil

The rate of water absorption of soil with silver coated hydrogel was less compared to the soil with or without hydrogels. The water desorption ratio of soil without silver coated hydrogels reached 62.3 and 90.2 wt% on 15th and 30th day respectively and soil with hydrogels reached 59.6 and 82.6 wt% on the 15th and 30th day respectively. The soil with silver coated hydrogel was 55.7 and 78.6 wt% (Fig. 3). The time needed for 50.0 wt% water evaporation was 12.2 and 13.5 days for the soil without silver coated hydrogels and with hydrogels respectively, while it was 14.6 days for the soil with silver coated hydrogels. The soil moisture desorption curve indicated that after 20 days, the volumetric water content of the soil without application of silver coated hydrogel was 9.8 % and with hydrogels was 11.4 %, while that of the soil with silver coated hydrogel was 21.4 %. Thus, silver coated hydrogel had good water-retention capacity in soil, and that with silver coated hydrogel use water can be saved and managed so that they can be effectively used for the growth of plants. These results showed that the silver coated hydrogel had excellent water absorbency, water-retention, and moisture preservation capacity. The reason was that the superabsorbent polymer silver coated hydrogel could absorb and store a large quantity of the water in soil, and allow the water absorbed in it to be slowly released with the decrease of the soil moisture. The swollen silver coated hydrogel was just like an additional nutrient reservoir for the plant-soil system. Consequently, it prolonged irrigation cycles, reduced irrigation frequencies, and strengthened the ability of plants to tolerate drought stress. Mahdaviniaet al., in the year 2014 reported that in the studies of efficiency of tested clay types and their holding, absorption capacity and its removal efficiency is 99 and 92 % for Clay5 and Clay3, it is only 88 % for hydrogel without clay (Clay0). The dye adsorption capacity depends on the concentration of Na-MMt can be attributed by inclusion of the nanoclay Na-MMt into hydrogel, because of negative surface of clay, the negative charge density will be increased.

2.4 Water-retention behavior of silver coated hydrogel in soil

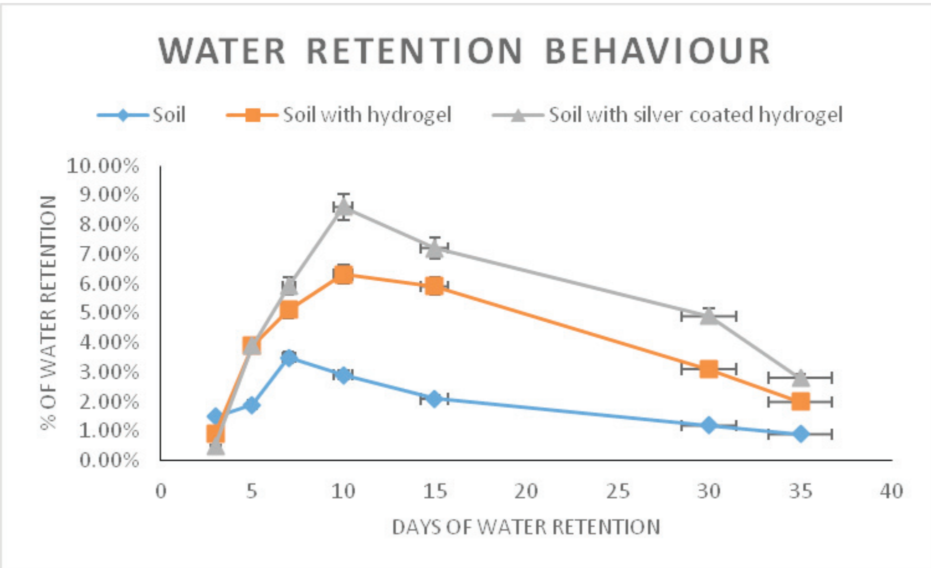

Figure: 3 Water retention behaviour

3.0 Conclusion

In the present work the compatibility of silver coated hydrogels were tested and the probability of using this system to modificate the polyacrylate hydrogel was assessed. Some of the prepared hydrogels reached higher values of swelling in saturated solution than the original unmodified material. This allows to decrease the content of polyacrylate component in the composite hydrogel and to reduce the content of non-biodegradable residues in soil after using hydrogel as water and nutrient regulator in agricultural applications. The results of experiment showed that the product has excellent water-retention capacity which could be especially useful in rainfed agriculture.

References

Akhter, J., Mahmood, K., Malik, K.A., Mardan, A., Ahmad, M. and 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 Environ, 50:463–469.

Ali, M.A., Rehman, I., Iqbal, A., Din, S., Rao, A.Q., Latif, A., Samiullah, T.R., Azam, S. and Husnain, T. (2014).Nanotechnology: A new frontier in Agriculture. Nanotechnology, a new frontier in Agriculture. Adv. life sci., 1(3):129-138.

Bajpai, A., Tripathi, N. and Saxena, S. (2014). Nanocomposites Based on Natural Biodegradable Materials: Effect of Post-Preparative γ-Irradiation on the Swelling Properties. Open Journal of Organic Polymer Materials, 4:10-15.

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

Buchholz, F.L. and Graham, T. (1998). Polyether-Modified Poly (acrylic acid): Synthesis and Applications.Mod. Sup. Abs. Polym. Tech, 37:4267–4274.

Henderson, J.C. and Hensley, D.L. (1985).Ammonium and nitrate retention by a hydrophilic gel.Hort. Sci, 20:667–668. Ingram, D.L. and Yeager, T.H. (1987). Effect of irrigation frequency and a water-absorbing polymer amendment on Ligustrumgrowth and moisture retention by a container medium. J. Environ. Hort, 5:19–21.

James, E.A. and Richards, D. (1986). The influence of iron source on the water-holding properties of potting media amended with water-absorbing polymers. ScientiaHor, 28:201-208.

Johnson, M.S. and Veltkamp, C.J. (1985).Structure and functioning of water-storage agriculture polyacrylamides.J. Sci. Food Agric, 36:789- 793.

Kayalvizhy, E. (2014). Synthesis and Characterization of Poly (N-tertamylacrylamide-co-Acrylamide/Sodium acrylate) Gold Nanocomposite Hydrogels.Paripex-Indian Journal of Research, chemistry, 3(5):23-26.

Khadem, S.A., Galavi, M., Ramrodi, M., Mousavi, S.R., Rousta, M.J. and Rezvani-moghadam, P. (2010). Effect of animal manure and super absorbent polymer on corn leaf relative water content, cell membrane stability and leaf chlorophyll content under dry condition. Australian J.of Crop Sci, 4(8):642-647.

Liu, Z., Jiao, Y., Wang, Y., Zhou, C. and Zhang, Z. (2008).Polysaccharides-based nanoparticles as drug delivery systems.Adv. Drug Deliv. Rev, 60:1650–1662.

Mahdavinia, G.R., Baghban, A., Zorofi, S. and Massoudi, A. (2014). Kappa-Carrageenan Biopolymer-Based Nanocomposite Hydrogel and Adsorption of Methylene Blue Cationic Dye from Water. J. Mater. Environ. Sci, 5(2):330-337.

Mura, S., Seddaiu, G., Bacchini, F., Roggero, P.P., and Greppi, G.F. (2013).Advances of nanotechnology in agro-environmental studies. Italian Journal of Agronomy, 8(18): 127-140.

Sachiko Kaihara Nitta and KeijiNumata (2013).Biopolymer-Based Nanoparticles for Drug/Gene Delivery and Tissue Engineering. Int. J. Mol. Sci, 14:1629-1654.

Wang, Y.T. and Boogher, C.A. (1987).Effect of a medium-incorporated hydrogel on plant growth and water use of two foliage species.J. Environ. Hort, 5:127–130.

Woodhouse, J.M. and Johnson, M.S. (1991).The effect of gel-forming polymers on seed germination and establishment.J. Arid Environ, 20:375–380.

Zohuriaan, M.J. and Kabiri, K. (2008). Superabsorbent Polymer Materials: A Review. Iran. Polym. J, (17): 451–477.