USE OF DIAPER POLYMERS AS SOIL CONDITIONER

Shahidian S., Serralheiro R.P., Serrano J., Machado R., Toureiro C., Rebocho J.
Instituto de Ciências Agrárias Mediterranicas, Universidade de Évora, Herdade da Mitra, Évora, Portugal.
Tel: 266760823. shakib@uevora.pt

1 INTRODUCTION

Super absorbent polymers (SAP) are white sugar-like hygroscopic materials mainly used in disposable diapers. SAPs are made of hydrophilic networks that can absorb and retain huge amounts of water or aqueous solutions. They can uptake as much as 1000 g g^{-1} water in relation to their own weight. Over the past years there has been a continuous reduction in their price and a generalized use of disposable diapers in the developed and some parts of the developing world. Although there are no global statistics, each child uses approximately 30 kg of polymers in his first two years of life, filling the landfills with around 400 kg of waste.

However, diapers are not necessarily un-reusable waste, and SAPs have been successfully used as soil amendments to improve the physical properties of soil in view of increasing their water-holding capacity and/or nutrient retention, especially in sandy soils. SAP hydrogels potentially influence soil permeability, density, evaporation, and infiltration rates of water through the soils. Potentially, the hydrogels can reduce irrigation frequency and compaction tendency, stop erosion and water run off, and increase the soil aeration and microbial activity.

The objective of this ongoing study is to evaluate the viability of recycling used diaper filling in agriculture, as a soil amendment. To achieve this goal, the effect of diaper filling on soil available water, crop water stress and production need to be studied, since diapers contain varying amounts of bleached cellulose fiber and other additives besides SAPs which influence the overall effect of diaper addition to the soil. In this particular study, the effect of application of diaper filling on an open air autumn lettuce is studied.

1.1 Previous experiments with SAPs in Agriculture

Diaper filling is mainly composed of a mixture of cellulose fiber and SAPs packed between two layers of polyethylene. Over the years, and in an attempt to make the diapers thinner, the fibers have been progressively replaced with SAPs, and today a diaper may contain as much as 10 g of SAP. For the diaper industry, the polymer must be able to absorb liquids even when it is being pressed, and thus the research has been towards material with a high absorbency under load (AUL) at the cost of free absorbency. Present day materials have a 30 g g^{-1} AUL, while the free absorbency has decreased to about 50 g g^{-1} under saline conditions (Zohuriaan-Mehr et al. 2008).

Over the past three decades both soluble and insoluble polymers have been used in agriculture. Water-soluble polymers such as polyacrylamides (PAM) have been used extensively (Lentz and Sojka, 1994; Santos and Serralheiro, 2000) to stabilize soil structure and thus increase infiltration and reduce runoff and erosion. Insoluble water-absorbing polymers have a great water-absorbing and gel-forming ability and can be divided into three main groups: the starch-graft co-polymers, which involve grafting of polyacrylonitrile into corn starch, and can absorb 300-1000 times their weight in water; the polyacrylate type which is made by polymerizing acrylic acid into long molecular chains and is widely used in disposable diapers; and the acrylamide-acrylate co-polymers which are sometimes marketed for agriculture, because of their great capacity to expand and absorb water under pressure, thus not only providing plants with water, but also helping to aerate the soil (Johnson, 1984).

Research has found that the hydrogels reduce irrigation frequency and compaction tendency, stop erosion and water run off, and increase the soil aeration and microbial activity (El-Rehim et al. 2004; Callaghan et al. 1989; Huttermann et al. 1999). The effect of an amendment of sandy soil with highly cross-linked polyacrylamide (Stokosorb K400) on the survival of *Pinus halepensis* (Aleppo pine) seedlings during water stress was investigated by Huttermann et al. (1999). Different concentrations of the hydrogel were added to sandy soils at 0.04, 0.08, 0.12, 0.20 and 0.40% w/w. The survival rates in 0.4% hydrogel were doubled compared to no hydrogel amendments. The hydrogel also allowed for 19 days tolerating drought.

Sivapalan (2001) reported amount of water retained by a sandy soil at 0.03 MPa pressure was significantly increased by 23 and 95% with addition of 0.03 and 0.07% polymer, respectively. It was reported that water use efficiency for plants increased by 12 and 19% with the application of 0.03 and 0.07% w/w polymer, respectively.

The effect of an hydrogel (Stokosorb K 410) on growth and ion relationships of salt resistant woody species, *Populus euphratica*, were studied by Chen et al. (2004). Addition of 0.6% w/w hydrogel to saline soil improved seedling growth (2.7 fold higher biomass) during a period of 2 years. Root length and surface area of treated plants was 3.5 fold more than those grown in untreated soil. It was reported that hydrogel treatment enhanced Ca^{2+} uptake and increased capacity of *Populus euphratica* to exclude salt (i.e. reduces contact with Na^+ and Cl^-).

The rate of hydrogels used in research studies varies and can range between 1.2 kg m^{-3} (Foster, 1990) to 16 kg m^{-3} (Gehring and Lewis, 1980), while Baker (1991) has recommended a rate of 1-1.5 g kg^{-1} of soil.

The SAPS used in agriculture are polyelectrolyte gels often composed of acrylamide and potassium acrylate. This makes them swell much less in the presence of monovalent salts and collapse in the presence of multivalent ions, that might exist in the soil or be part of fertilizers. Even under these conditions, the uptake capacity can still be as high as 30-60 g g^{-1} (Bowman et al., 1990).

The soil solution of the mine waste heap amended with SAP had a 30% lower NaCl and a 50% higher Ca^{2+} concentration compared to that of the untreated mine heap. The concentration of NaCl in the tissues of the *P. euphratica* plants was 50% lower in those growing on the SAP amended mine heaps compared to the control plants. These results suggest that hydrogel incorporation into the soil reduced apoplasmic ion transport into the inner root. This contributed to the restriction of subsequent root-to-shoot salt transport, enhancing the salt exclusion capacity of *P. euphratica* (Chen et al, 2004).

Most SAP materials are moderately bio-degraded in the soil by the ionic and microbial media and convert finally to water, carbon dioxide and organic matter, leaving no undesirable chemicals in the soil or the environment. (Barvenik et al, 1994; Stahl et al, 2000). Little or no consistent adverse effect has been shown on microbial populations and their toxicity for mammals is very low (oral LD50 for rat ~5000 mg kg^{-1}), in as much as they are extensively used in hygiene products, where they can easily come in touch with human skin or even be swallowed by infants.

2 MATERIALS AND METHODS

The experiment was carried out at the Mitra Research Station, located in the south of Portugal. The soil is a FAO Luvissol that has been enriched through many years of cultivation.

In this experiment only new diapers were used in order to isolate the influence of the diaper SAP and fiber from that of the urea and other organic compound present in used diapers. The treatments were thus: Control: 0g diapers m^{-2} and Treatment: 100g m^{-2} clean diaper filling (fiber plus SAP). The polyethylene wrapping and other plastics were separated by hand from the diapers and discarded, since they are not biodegradable and create barriers to root growth and mechanical operations.

The experiment was divided in randomized blocks with two treatments (treatment and control) and three repetitions. The treatment plots received 100g m^{-2} of dry diaper content (the equivalent of 10 diapers), which was mixed in the 0.2 m topsoil prior to planting. This is roughly equivalent to 0.2 g kg^{-1} of soil, which is on the lower side of the values recommended by the bibliography. The Planting was done on 27 September 2009. Lettuce was planted in double lines spaced 30cm within row and 75 cm between rows.

Soil moisture content was measured by EC-5 dielectric constant Echo probes buried at 7.5-12.5 cm and 15-25 cm. soil temperature was also measured at the same depths. Wind speed, global radiation, air temperature at 0.25 and 1.75 m height were also measured. Readings were made continuously at 15 min intervals. For each treatment plant temperature was measured through infrared thermometer positioned at 0.5m height.

3 RESULTS AND DISCUSSION

A total of nine irrigations were carried out in the growth period of the crop, in order to maintain the soil water content above 10 cm^3 cm^{-3}. On November 12th (45 Days after planting) the crop was harvested and weighed.

Data from the soil humidity sensors show that the soil in the treatment had slightly lower moisture content than the control (Fig. 1). For example in the DOY 279 and 280 the soil humidity was an average of 0.02 cm^3 cm^{-3} less in the treatment when compared to the control. This observation is not in agreement with the literature which indicates higher moisture retention with the application of SAPs, and the only possible explanation is that the treatment provided more water to plants in the early stages of development, leaving less available water for the later stages of growth.

Regarding canopy temperature, data show that the leaves were generally warmer than air, especially during the 12.00-15:00 h period of greatest heat. The data also show that the treatment plants had a slightly higher temperature than control plants. This observation is in agreement with the lower soil moisture content, and indicates greater water stressed plants as a result of depleted soil moisture. Nevertheless, the plants seem to recover after sunset, and show the same behavior as control plants until around 10.00 in the following day.

Using data from a 10 day period (day 30 to 40 after planting) it is possible to observe that in control, the canopy starts to be markedly cooler than the air for temperatures above 25ºC (Fig. 2), while in the treatment plants, the same is true but only after about 29ºC. These data indicate the existence of a threshold temperature for the stoma to close and avoid excessive transpiration. It is also possible to observe the beneficial influence of the treatment, which leads to cooler canopy temperatures when air temperature increases above 29ºC.

The average weight of the lettuce plants in each repetition are presented in Table 1. These data show that the application of 100g m^{-2} of diaper fiber and SAP decreased the average weight of the lettuce from 471.7g to 408.5g. The results are statistically significant.

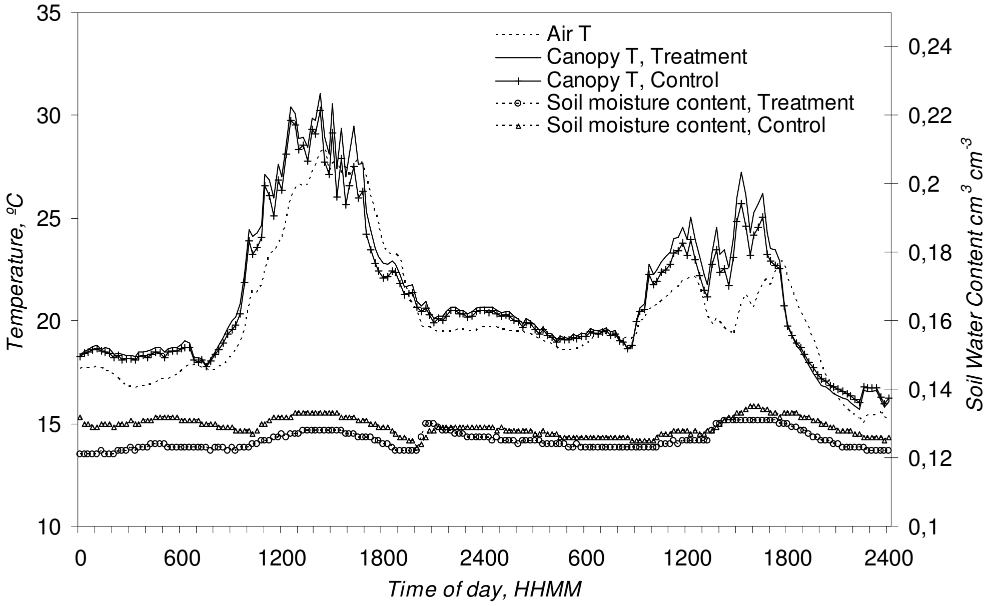

FIGURE 1 **Evolution of air and canopy temperature and their relation with soil moisture in both treatments, during DOY 279 and 280.**

4 CONCLUSIONS

Diaper filling (cellulose and SAPs) were added to soil at the lower limits recommended by literature. The results indicate that the adding of diaper filling had a negative effect on both available soil water and crop production. These data are not in line with the general finding of other researchers that found SAPs to add to soil available water and increase crop survival and production.

It is thus necessary to carry out further experiments, especially with different concentrations of diaper fillings and different crops in order to encounter the right balance for using diaper fillings as a soil ameliorant.

TABLE 1 **Average fresh weight of the lettuce plants in each repetition. Harvest was on DAP 45.**

	Control	Treatment	Average
Repetition 1	389.8	353.2	371.5
Repetition 2	494.9	399.5	447.2
Repetition 3	530.3	472.8	501.5
Average	471.7	408.5	440.1

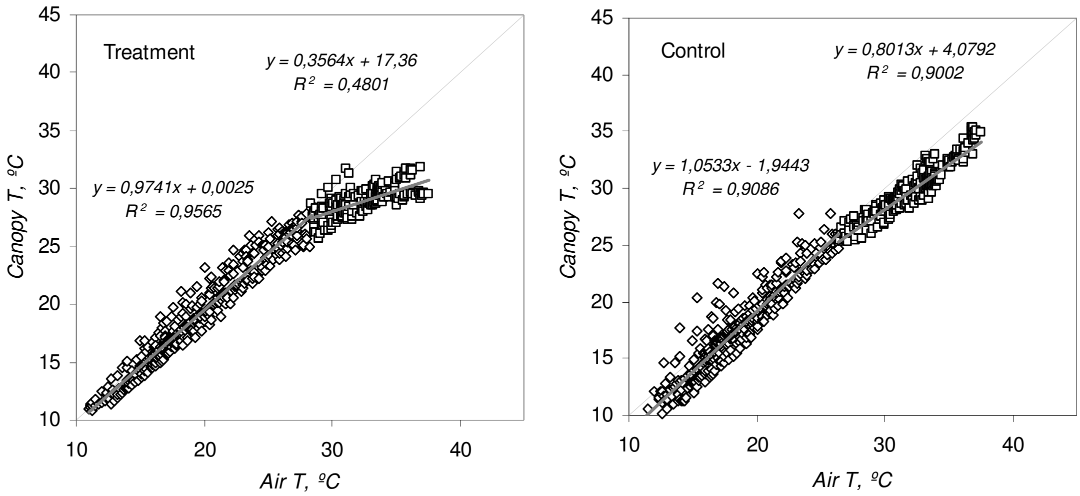

FIGURE 2 **Effect of the treatment on the canopy temperature between days 30 and 40 after planting (DAP).**

REFERENCES

Baker S W 1991. The effect of polyacrylamide co-polymer on the performance of Lolium perenne L. turf grown on a sand rootzone. J.Sports Turf Res. Inst. 67, 66-82.

Barvenik F W 1994. Polyacrylamide characteristics related to soil applications, Soil Sci, 158, 235- 243.

Bowman D C, Evans R Y, Paul J L 1990. Fertilizer salts reduce hydration of polyacryamide gels and affect physical properties of gel-amended container media, J Amer Soc Hort Sci, 115, 382- 386.

Callaghan T V, Lindley D K, Ali O M, Abd H El Nour, Bacon P J 1989. The Effect of Water-Absorbing Synthetic Polymers on the Stomatal Conductance, Growth and Survival of Transplanted Eucalyptus microtheca Seedlings in the Sudan. Journal of Applied Ecology, 26 (2), 663-672.

Chen S L, Zommorodi M, Fritz E, Wang S, Huttermann A 2004. Hydrogel Modified Uptake of Salt Ions and Calcium in Populus euphratica under Saline Conditions, Trees Struct. Funct., 18, 175.

El-Rehim H A, Hegazy E S A, El-Mohdy H L 2004. Radiation synthesis of hydrogels to enhance sandy soils water retention and increase plant performance, J Appl Polym Sci, 93, 1360- 1371.

Foster W J, Keever G J 1990. Water absorption of hydrophylic polymers (hydrogels) reduced by media amendments. J.Environ. Hort. 8, 113-114.

Gehring J M, Lewis A J 1980. Effect of hydrogel on wilting and moisture stress of bedding plants. J. Amer. Hort. Sci. 105, 511-513.

Huttermann A, Zommorodi M, Reise K 1999 Addition of hydrogels to soil for prolonging the survival of Pinus halepensis seedlings subjected to drought, Soil and Tillage Research. 50(3-4), 295-304,

Johnson 1984. The effects of gel-forming polyacrylamides on moisture sotrage in sandy soils, J. Sci.Food Agric. 35, 1196-1200.

Lentz R D, Sojka R E 1994. Field Results Using Polyacrylamide To Manage Furrow Erosion and Infiltration. Soil Science. 158(4).

Santos F L, Serralheiro R P 2000. Improving Infiltration of Irrigated Mediterranean Soils with Polyacrylamide. Journal of Agricultural Engineering Research. 76(1), 83-90.

Sivapalan S 2001. Effect of Polymer on Soil Water Holding Capacity and Plant Water Use Efficiency. In Rowe B et al (eds) Proceedings of 10th Australian Agronomy Conference. Tasmania

Stahl J D, Cameron M D, Haselbach J, Aust S D 2000. Biodegradation of superabsorbent polymers in soil, Environ Sci Pollut Res, 7, 83-88.

Zohuriaan-Mehr M J, Kabiri K 2008. Superabsorbent Polymer Materials: A Review.Iranian Polymer Journal. 17(6), 451- 477.