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NOVEL BIODEGRADABLE SUPER ABSORBENT MATERIALS FOR AGRICULTURE IN ARID AND DESERT REGIONS

by

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04-0117

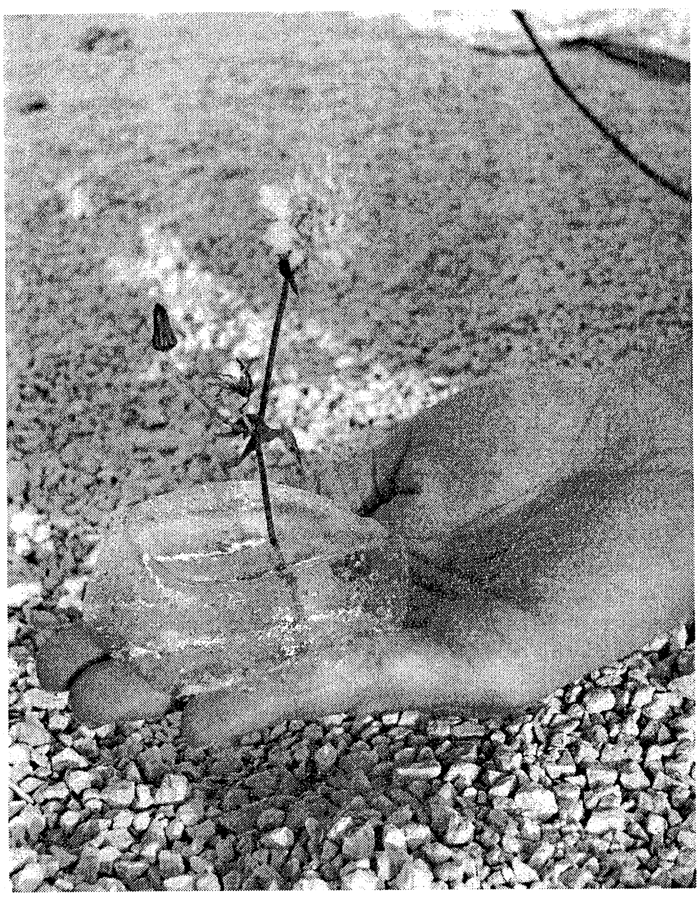
Abstract

A novel class of biodegradable materials has been developed to be used as a controlled release system for water and nutrients to cultivations in arid and desert regions. This is an hydrogel able to absorb up to two liters of water per gram of dry material. Once absorbed, the water is slowly released to the cultivation together with nutrients, providing a constant irrigation and significantly reducing the waste in layer.

The results of this research offer an actual and feasible solution to the challenging problem of the supply of water sources and the optimisation of their use. This problem is particularly striking in many areas of the South of Italy, emphasized by the progress of marine inclusion, which in many regions increases salt content in water, making it unusable for agricultural purposes. Moreover, it offers several advantages for the cultivations in greenhouses and protected environments, which display a significant growth in the last years, pushed by the increased demand for the out of season agricultural products. Moreover, it act towards the achievement of standard production, both in terms of products quantities and quality.

Three international patents have been performed on this material, the industrial scale up of the production process of the hydrogel is under development, together with a project to test its efficiency.

Keywords: Hydrogels, Polymers, Superabsorbent, Cultivation, Arid



I. INTRODUCTION

They are called superabsorbent hydrogels, and industrially are commercialised as SAP (Super Absorbent Polymers), due to their capacity to absorb water in amount which can be as high as 5 liters per gram of dry material [1]. They are already present on the market, and for the only diapers market, in year 2000, about 800,000 tons have been produced. They are, in general, made up by acrylamide based products and, thus, are not biodegradable.

Renewed attention of Institutions and public opinion toward low environmental products manufacturing has been pushing the research toward the synthesis of natural based and biodegradable superabsorbents, which still maintain the same physical and absorbent properties of the synthetic ones.

Promising results have been obtained with cellulose derivatives based hydrogels, stabilized by chemical crosslinks, which we present in this work. They are able to absorb up to 1,800 times their initial weight in water, a value which is significantly higher than the non biodegradable products on the market nowadays, characterized by an average sorption capacity of about 500 times their initial weight in water.

Figure I.1: Dry ad swollen state of a cellulose based superabsorbent hydrogel.

In addition to the material's synthesis development, which has been set up also for a large scale production, a wide analysis has been carried out on the correlations between the hydrogel chemical-physical structure and its sorption properties, with the aim of designing the optimal structure for each application. Advanced technologies and innovative investigation methodologies have been developed to carry out the study, and three international patents have been performed on the material [2-5].

The most promising and innovative application of this class of materials is in the field of agriculture, and provides an actual solution to the problem of cultivation in arid or desert regions, the supply of water sources and the optimization of their use. This problem is particularly striking in many areas of the South of Italy, emphasized by the progress of marine inclusion, which increases salt content in water, making it unusable for agricultural purposes.

This application consists in innovative cultural systems based on superabsorbent materials, which are able to maintain an optimal degree of humidity in the soil, acting as water reservoir and providing a significant decrease of water waste. Moreover, they can act as a controlled release medium of nutrients for the cultivation, which are provided together with water for a period of time which can be also longer than a week. Mechanisms of nutrients loading in the hydrogel, together with the release kinetic to the soil are still under investigation. Test on different type of cultivations have been sponsored by the Italian Ministry of Research, together with the scale up of the production process.

A preceding study has been performed by a Japanese multinational company in the Egyptian desert with a non biodegradable superabsorbent, which demonstrated the validity and effectiveness of this method. However, the non biodegradable material had two important drawbacks, which prevented its further development: the first was that it remains in the soil after use in form of powder, which cannot be easily removed and thus acts as a polluting agent. The second is a problem of toxicity, due to the eventual presence in the material of unreacted acrylamide which, even if in low amounts, is highly toxic for the both the soil and the resulting cultivation itself.

The biodegradability of the superabsorbent presented in this work, and its sorption capacity which is even higher than the product tested in the Egyptian desert, make it a strong candidate for the solution of the water supply problem in desert regions with growing desertification.

In the first part of this work we will present, briefly, the problems related to the actual cultivation systems in arid environments and the present contest of the technology under investigation. Then, the cellulose based superabsorbent hydrogel will be described, with a special focus on its sorption properties both in free state and under compressive stress field, which is provided by the soil or sand surrounding the material in its actual operative conditions. Finally, the cultural technology will be analysed in detail, together with the results obtained in the Egyptian desert with the non biodegradable materials.

II. RELEVANT PROBLEMS RELATED TO ACTUAL CULTIVATION SYSTEMS

The problem of unavailability of water resources is particularly striking in Italy, and primary involves Regions in the South; however, it also involves many Countries in the Mediterranean basin, where desertification phenomenon is increasing every year. Moreover, many regions at growing desertification have long tracts of coasts, and the marine inclusion deeply increases water salinity, often to such an high percentage that it is not more suitable for cultivation purposes.

Just on the basis of these first considerations, the development of an agricultural system which allows to reduce the waste of water during irrigation seems to be of a particular interest.

In addition to this, there are many other considerations, which are not under the spot light but have still a profound impact on the agricultural system, which make the saving of water resources a fundamental issue in modern cultivation technology. These are briefly described in the following.

A. CULTIVATION IN PROTECTED ENVIRONMENT

In the last few years, the area reserved to cultivation in protected environment are significantly increased, especially in Campania, Puglia, Sicily, and Calabria Regions, pushed by the increased demand for out of the season and standard products, both in qualitative and quantitative terms. Of the overall about 26,000 hectares destined to cultivation in protect environment in Italy, more than 50% are concentrated in Campania and Sicily Regions.

The field of protected cultivation is characterized by an high intensity and specialty, involving the succession of the same type of products (also in terms of variety), which leads to problems of field 'fatigue', accumulation of pathogenic telluric agents, secondary salinity due to the massive use of fertilizing and/or salt water.

To overcome some of these problems, a wide use of pesticides is diffused, such as the methyl bromide, for which Italy is the second consumer in the world (after United States) and first in Europe. The use of such a product, which nowadays is already restricted, will be definitely prohibited within year 2005 (Montreal protocol), due to the risk of bromine accumulation, which is toxic for humans, for the field, for the water layer and in the horticultural products; moreover, methyl bromide is included in the class of substances which promote the hole in the ozone layer.

Thus, the use of products able to modulating the nutrients contribution to the cultivation would avoid the accumulation of toxic substance in the field, and a significant reduction of the amount of water necessary for the cultivation would allow the use of non salt water, reducing, in turn, field salinity.

B. CULTIVATION 'OUT OF SOIL'

Systems of cultivation 'out of soil' have been introduced with the aim of releasing the plants cultivation from the soil and all the problems related to its use. In recent years they are increasing significantly due to the restrictions connected to the use of methyl bromide.

'Out of soil' systems consist in methods and techniques aimed to the plant growth with the roots directly in contact with a nutrient solution (water and fertilizer), with or without the use of a solid medium acting as a mechanical support for the plant itself.

These kinds of cultivation systems are divided, in general, in two main classes: open cycle and closed cycle systems. The first are characterized by the fact that the solution is dispersed in the environment after one passage trough the roots; in the second case, the solution is recovered and reintroduced in the cycle. The problem of the open cycle systems is the waste, in the environment, of high percentage of nutrient solution: it has been estimated that drain percentage of 20-30% result, on a year basis, in the introduction in the environment of about 2,000-3,000 m3/ha of nutrient solution, which contain up to 8 tons of fertilizing agents, mainly nitrogen based.

Thus, the simple reduction of drain percentage, by means of a controlled release of nutrients by specific media, would provide a significant improvement of the environmental impact of these systems.

Also in the case of closed cycle systems, problems including capillary upstream and low retention capacity would be overcome by the use of materials with an high sorption capacity in water solutions.

C. NITROGEN IN WIDE FIELD CULTIVATIONS

It is a common and diffused tendency the distribution in the soil of synthetic fertilizers in amounts exceeding the actual cultivation needs; this is valid in particular for nitrogen, which is able to highly stimulating the plant growing activity. This has two important drawbacks, both on product quality and on the environment.

In terms of product quality, nitric fertilizers distribution increases NO3 concentration in the solution circulating in the soil, thus increasing sorption phenomena, translocation and accumulation of nitrates in the plant (cellular shaped vacuum). The accumulation of high quantities of nitrates decreases, in turn, the nutritional value of vegetables. By food ingestion, moreover, nitrates arrive in the stomach, where they are reduced to nitrites, which in presence of ammine can generate carcinogenic substances (nitrosammines).

For these reasons, Health Authorities of many European countries such as Holland, Germany, Austria, Switzerland and Belgium, fixed maximum values for nitrates content in foods which represent the principal source of nitrates and nitrites (namely vegetables, sausages, smoked fish, cheese, baby foods, and drinkable water).

In terms of environmental impact, excess of nitrates in the rizosphere can cause the pollution of the superficial water due to its draining in the soil. In fact, the ion has an high mobility along the vertical profile in the soil, not being hold by the colloidal complex of the soil itself.

This problem pushed the research toward the use of natural and synthetic substances, able to modulating the availability of the element during the time as a function of the removal kinetic exerted by the cultivation.

Main objectives which can be achieved by use of the hydrogels presented in this work are the followings:

1) Minimize the nitrogen waste for nitrates draining (expecially during rainy seasons);
2) Regulating the nitrogen subministration (quantità, form and application periods) with the aim of reducing nitrates content and increasing the nutritional value of the products;
3) Avoid stress in the plants related to NO_3^- excess during its growth and reducing its sensitivity to parasites.

III. CELLULOSE BASED SUPERABSORBENT HYDROGELS

Soperabsorbent on the market nowadays are, in the greatest part, acrylamide based products, thus non biodegradable. Here we describe the fundamental steps involved in the development of a new class of biodegradable superabsorbents, to be used as water and nutrients release systems to cultivations in arid regions, and the main results are presented. This class of materials are also the ideal candidates to substitute non biodegradable superabsorbents in almost all their industrial applications.

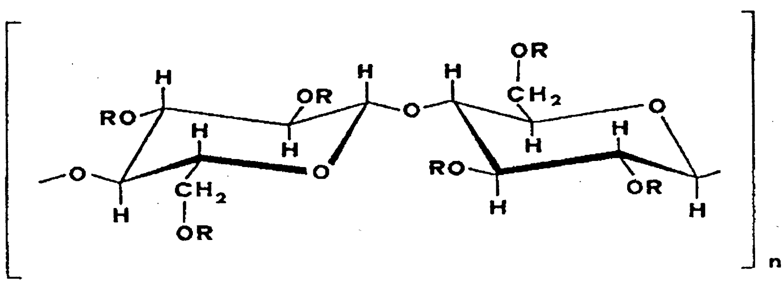
A. SYNTHESIS PROCEDURES

Chemical hydrogels are obtained by polymer chains stabilization through covalent bonds, by means of small molecules, called crosslinkers, which link two or more different chains, preventing their dissolution in liquid solvents.

Thus, two important parameters in the evaluation of network expansion properties are the chemical stricture of polymer chains and the length and flexibility of crosslinkers.

Hydrogels developed in this work have been obtained chemically crosslinking cellulose derivatives, and in particular a Carboxymethylcellulose sodium salt (CMCNa) and the Hydroxyethylcellulose (HEC).

Figure 3.1: The repeating unit of Carboxymethylcellulose (CMC) and Hydroxyethylcellulose (HEC)



NaCMC	**-H, $-CH_2COONa$**
HEC	**-H, $-CH_2CH_2OH$, $-CH_2CH_2OCH_2CH_2OH$,**
	$-CH_2CH_2OCH_2CH_2OCH_2CH_2OH$

Carboxymethylcellulose [6] presents all the features to be employed, once crosslinked, as a superabsorbent. In fact, this polymer is an highly hydrophilic, biodegradable cellulose derivative. It is also present on the market at a relatively low price. Moreover, it is a polyelectrolyte polymer, having a negatively charged group attached on the polymer backbone.

Hydroxyethylcellulose [7] is also a cellulose derivative, hyghly hydrophylic, but without any charged group on the backbone. In Figure 3.1 a scheme of both CMCNa and HEC repeating unit of the polymer chain is reported.

The difunctional Dyvinylsulfon (DVS) molecole has been used as a crosslinking agent for the network stabilization. A scheme of the crosslinking reaction, which is the mechanism joining of the polymer chains in a stabilized network acting as a mechanical support for the hydrogel, is reported in Figure 3.2.

Figure 3.2: The crosslinking reaction for hydrogel stabilization.

$$\text{(CMC/HEC)-OH} + \text{CH}_2\text{=CH-SO}_2\text{-CH=CH}_2 + \text{HO-(CMC/HEC)}$$

$$\xrightarrow{OH^-}$$

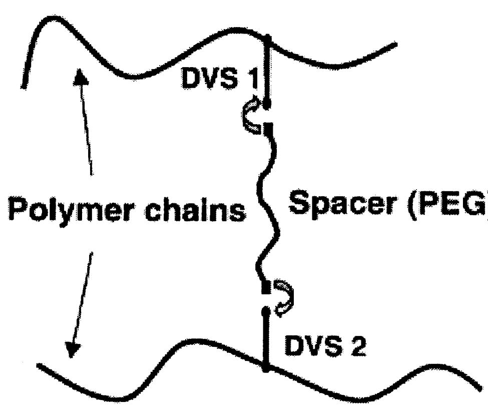
$$\text{(CMC/HEC)-O-CH}_2\text{-CH}_2\text{-SO}_2\text{-CH}_2\text{-CH}_2\text{-O-(CMC/HEC)}$$

Hydrogel is synthesized in an already swollen state, and thus a desiccation procedure is necessary in order to obtain a dry powder in the end use form. Desiccation can be carried out in three different ways: in air atmosphere at room conditions, under vacuum or by phase inversion in acetone. The desiccation procedure significantly affects both material's physical properties and its sorption capacity. Materials obtained by desiccation by phase inversion in acetone displayed the best performance.

Polymer network can be further modified, in order to improve material's swelling properties, adding to the crosslinker molecules other agents called molecular spacers. They are difunctional molecules which are added to the crosslinker increasing the average distance between two adjacent links, thus allowing the network to further expand once in contact with water. Polyethylenglycol (PEG) molecules have been selected as spacers.

As is represented in Figure 3.3, the spacer molecule links at their free ends two different DVS molecules, which are linked, in turn, to the polymer backbone. The resulting crosslinking bridge results, in such a way, significantly longer than the one which would be obtained using only the DVS, and also more flexible, thus allowing higher expansion capacity to the material once in contact with water or water solutions [8].

Figure 3.3: Hydrogel network with molecular spacer



B. MATERIAL'S PROPERTIES

Different techniques have been set up for the analysis of the material's chemical-physical and microstructural parameters. A detailed description of both procedure and results is reported in literature [9-12]. Here we describe, in brief, main results which are related to the application under investigation.

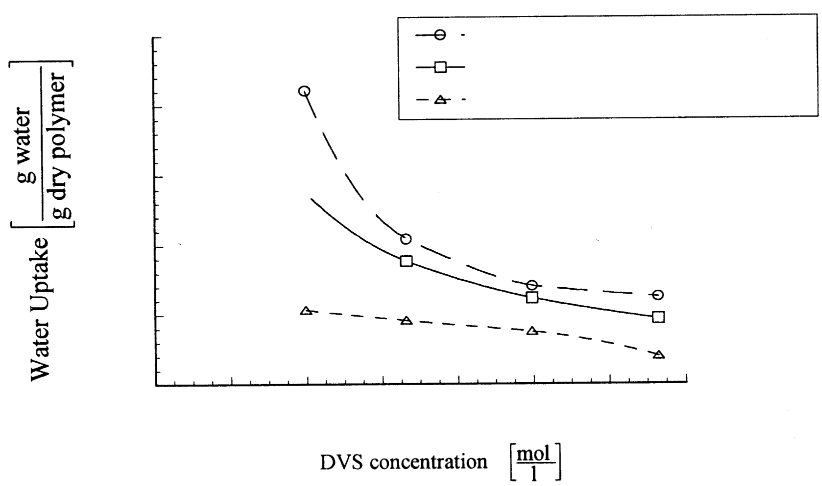
An important issue for the application in agriculture are the hydrogel sorption properties in water and water solution at different ionic strength and pH, as they resembles the actual environmental conditions of the material in contact with nutrient, fertilizers and soil. Tests have been carried out both swelling the material in free state or under compression, with the aim of simulating the compressive force acting on the hydrogel when it is supposed to swell surrounded by the soil.

Moreover, toxicity studies on the material have been carried out both in vitro, on selected cell lines, and in vivo, on rats. Any toxicity has been displayed by the material in all the test, as reported in literature [13, 14], thus encouraging its use for cultivations.

C. SORPTION PROPERTIES IN THE FREE STATE

The effects of chemical composition and desiccation procedures were assessed studying the swelling properties of hydrogel samples in water. The swelling degree as a function of DVS concentration is reported in Figure 3.4 for samples obtained starting from the same CMCNa/HEC weight ratio equal to 3/1 and differing for desiccation procedures. The equilibrium water content increases as the crosslinking agent concentration increases. This trend is related to the increase of the network elastic response to swelling, because at higher DVS concentrations the average molecular weight between two crosslinking points decreases. Also, in this case, different sorption amounts were detected as the desiccation procedure was changed according to the same trend followed for the samples obtained at constant DVS concentration.

Figure 3.4: Swelling degree as a function of DVS concentration for samples obtained starting from equal CMCNa/HEC weight ratio (3 : 1) but differing for desiccation procedures.

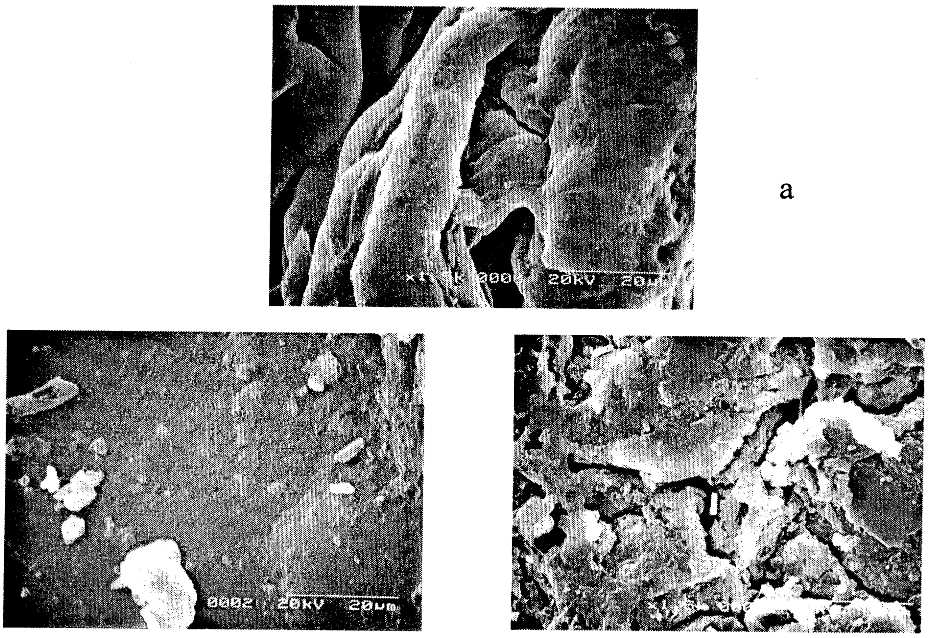


Desiccation procedures remarkably affect the swelling degree, and the highest water uptake is detected for the gel dried using extraction with acetone, while the lowest is for the gel desiccated at room conditions. This effect is related to the different sample morphologies obtained, as elucidated by the electron scanning micrographs of desiccated gel surfaces reported in Figure 3.5, clearly evidencing the morphological differences. The gel desiccated at room conditions [(b) in figure 3.5] is more dense and compact, while the acetone desiccated gel is characterized by a microporous structure [(a) in figure 3.5]. In the case of gel

desiccated under vacuum, an intermediate structure was observed [(c) in figure 3.5]. Therefore, differences in sorption behaviour can be explained in terms of the different macroscopic morphologies obtained. In fact, the structures characterized by a higher microvoids size show remarkably higher sorption uptakes, due to the fact that part of the water condensates in the microvoids whose dimension further increases after polymer swelling.

The presented experimental findings show different routes in obtaining cellulose-based superabsorbent materials characterized by a wide range of water sorption capabilities. Chemical composition, manufacturing procedures, and desiccation protocols can be biased to obtain a material suitable for the specific agricultural application.

Figure 3.5: SEM micrographs of dry hydrogel samples: (a) dried in acetone; (b) dried in air atmosphere at room conditions; (c) dried under vacuum.

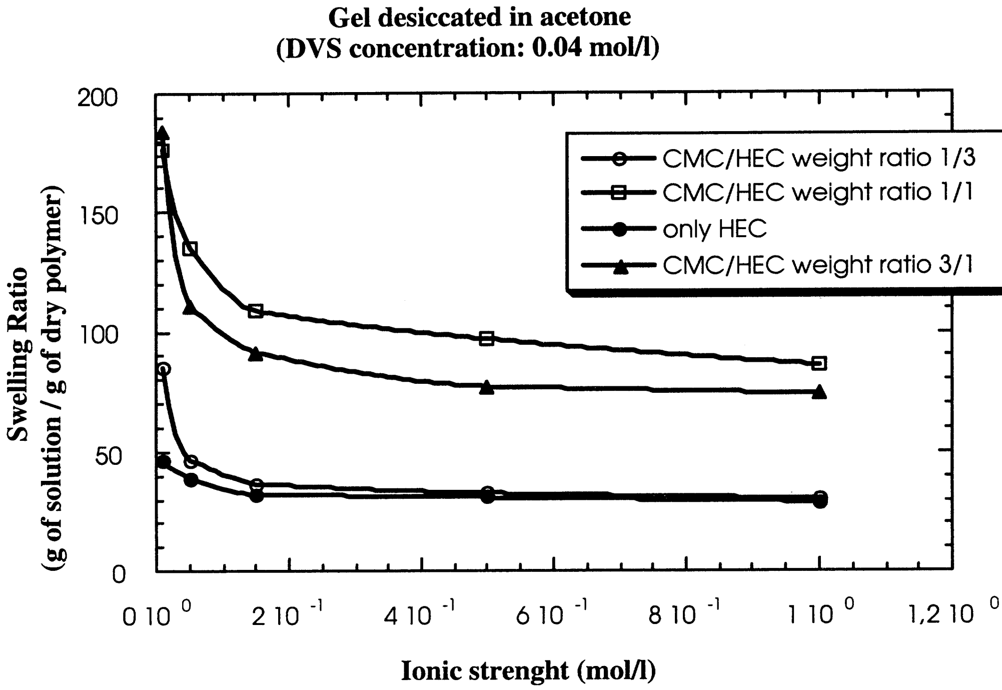


a

b

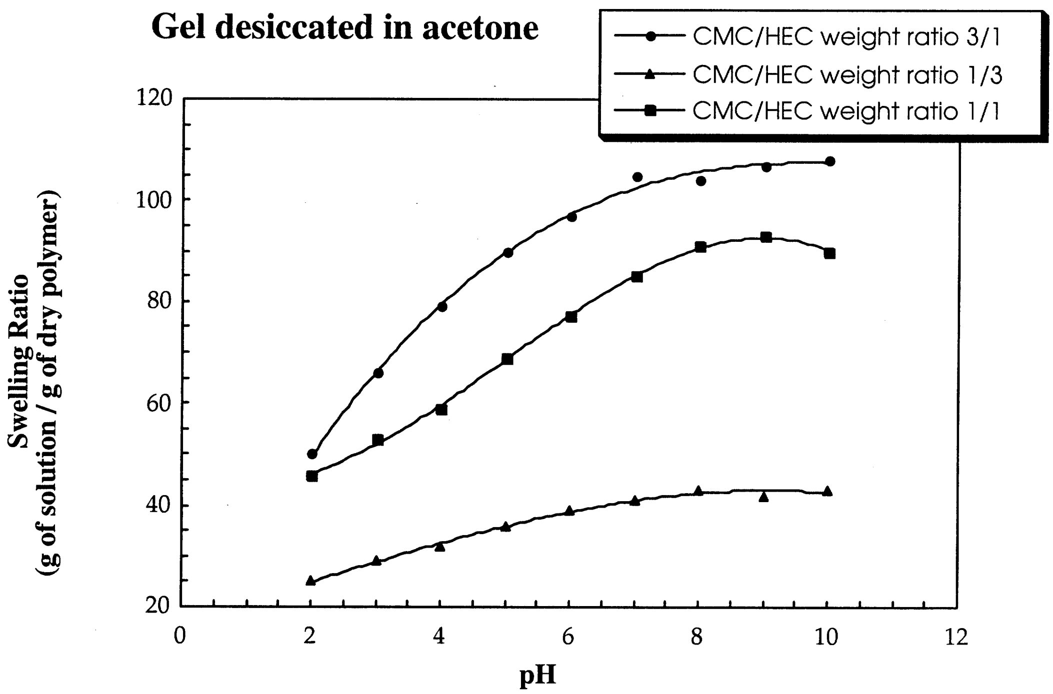
c

Figure 3.6: Plot of the swelling ratio vs ionic strength of the external solution. Samples obtained at fixed DVS concentration (0.04 mol/l) and varying the CMC/HEC weight ratio. All samples are dried in acetone.



In Figure 3.6 results of the swelling measurements in solutions at different ionic strength are reported. For all the hydrogel chemical and morphological compositions, it is generally observed a reduction of the swelling capacity increasing ionic strength of the external solution. This has been related to the polyelectrolite nature of polymer chains constituting the network. In fact, fixed charges on the CMC backbone play an essential rule in the absorption mechanism, both for network expansion due to the repulsion between charges of the same sign, and for a 'Donnan effect', which results in an osmotic pressure which regulates water flux through the hydrogel. Both these effects increase sorption capacity decreasing the ionic strength of the external solution.

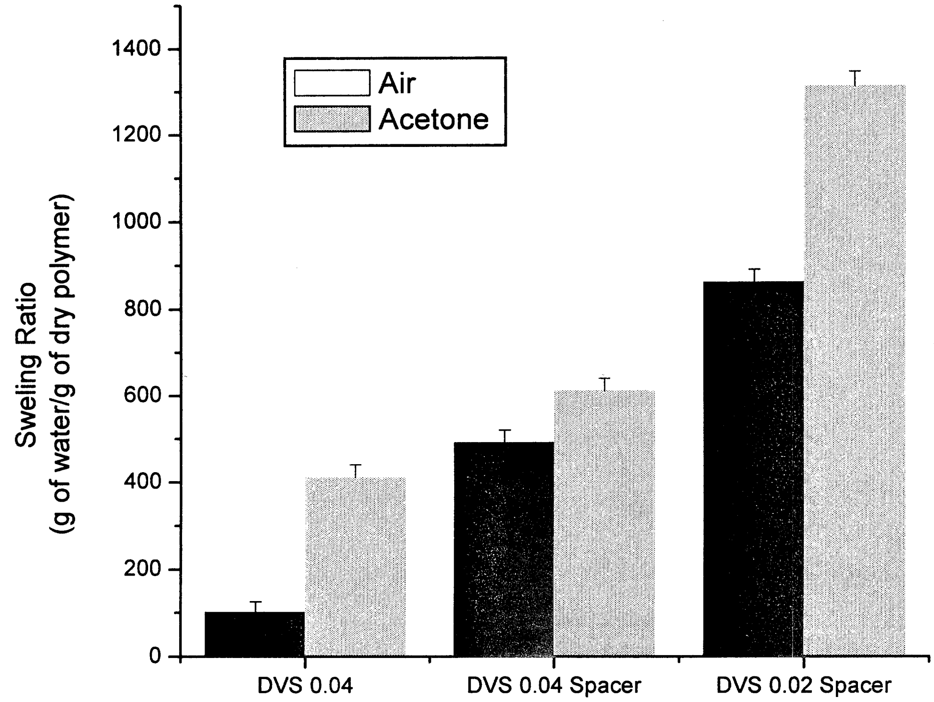
Figure 3.7: Plot of the swelling ratio vs the pH of the external solution. Tests have been performed keeping constant the ionic strength of the external solution and DVS concentration (0.04 mol/l), and varying the CMC/HEC weight ratio.



The pH of the external solution plays an analogous rule in terms of material's sorption capacity. In fact, changing the pH changes the degree of dissociation of the charges attached to the CMC chain, and in particular increasing the pH increases the number of charges, thus increasing hydrogel swelling properties, as shown in Figure 3.7.

Regarding the use of molecular spacers between the links of the polymer network, a measure of their effect on final hydrogel swelling properties has been performed both on samples desiccated in acetone and in air atmosphere at room conditions, and results are reported in Figure 3.8.

Figure 3.8: Hydrogel swelling ratio in distilled water versus type and concentration of the crosslinker in the reactive mix. Spacer is PEG with a molecular weight of 4600.



The presence of spacer significantly increases material's sorption capacity; in fact, the sample with a DVS concentration of 0.02 mol/l and desiccated in acetone displays a swelling ratio in water of about 1300 (i.e. it absorbs about 1300 times its initial weight in water).

It is also interesting that samples desiccated in air atmosphere at room conditions, in presence of spacers, have a sorption capacity of approximately 800 grams of water per gram of dry polymer. This is an important result by the industrial point of view, as this allows to avoid the desiccation procedure in acetone, thus reducing both process complexity and environmental impact.

D. SORPTION PROPERTIES UNDER COMPRESSIVE STRESS FIELD

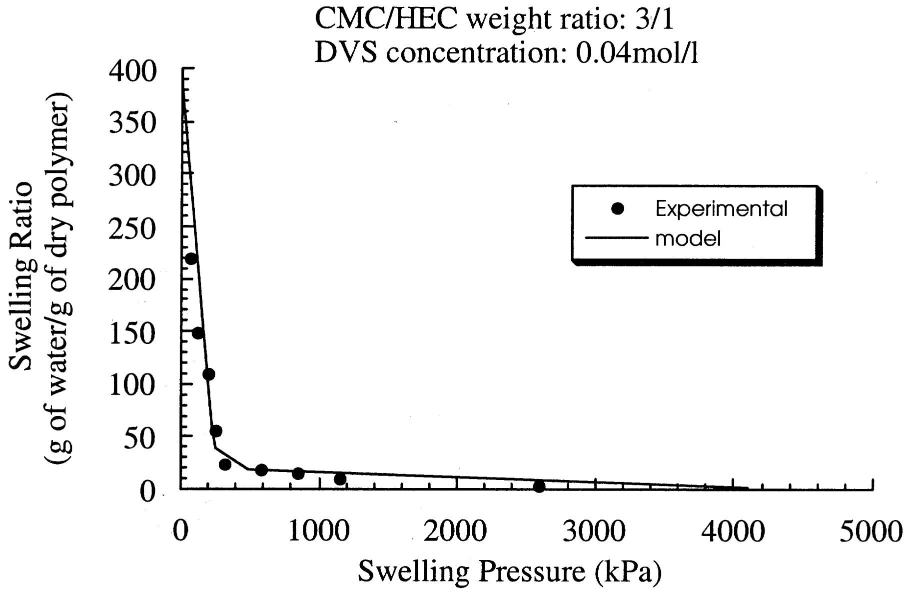
With the aim of evaluating material's sorption properties in an environment reproducing the actual operating conditions (hydrogel swelling when confined in the soil around plant roots), swelling test under compression have been carried out.

To this end, different apparatus have been set up, able to inducing an isotropic compressive stress field on the material during swelling, and evaluating its sorption behaviour in this condition.

A model able to predict hydrogel sorption capacity under stress has also been developed [15], and accurate results have been obtained.

In Figure 3.9 a comparison between sorption measurements results obtained during the tests and model predictions are reported, and a good agreement between the data has been obtained. It can be also observed that the material is able to absorb water even under high compressive load, and thus is able to perform also under stress significantly higher than the soil pressure.

Figure 3.9: Hydrogel swelling under isotropic compression: (·) the swelling ratio versus the swelling pressure and (–) interpolation model predictions. Experimental data have been interpolated by means of a mathematical model, developed on the basis of material morphology and sorption data. A good agreement between model prediction and actual data is displayed.



Moreover, tests of liquid release under centrifugation have been carried out, centrifuging the hydrogel at 1500rpm for five minutes. The hydrogel released less than the 10% of liquid during these tests, witnessing that the water release mechanism from the material to the soil is mainly a diffusion driven mechanism, as requested for a fine release regulation of both water and nutrients.

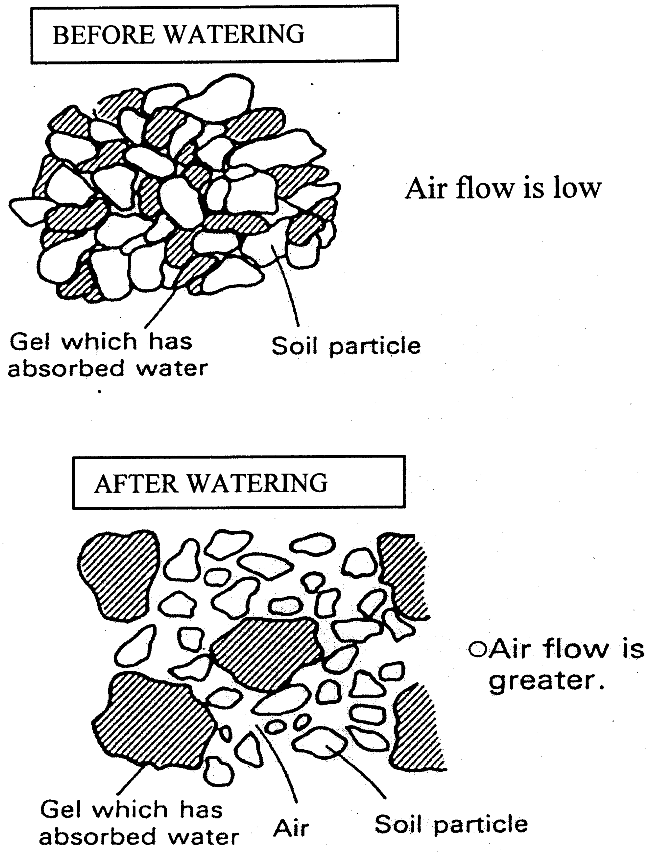
IV. THE APPLICATION IN AGRICULTURE

The mechanism of water release from the hydrogel to the cultivation is based on material's sorption and desorption properties, coupled to its high sorption capacity. The hydrogel is mixed to the soil (or other substrates) in dry form, and in form of grains with a dimension similar to that of the soil grains, in an area closed to the plant roots.

The soil is then watered only once, and the hydrogel swells absorbing water. Thus, liquid is released from the material to the soil, by a diffusive mechanism, when the gel is in contact with an environment which is dry or at a lower humidity level. In such a way, water or water solution which is not absorbed by the roots is not lost, but stored in the hydrogels which act as a water reservoir, keeping a constant humidity level in the soil or the substrate.

It is also possible to charge the material with nutrients and/or fertilizers, specific for each cultivation, which are then released in controlled time and conditions. Moreover hydrogel grains, which in the dry state have the same dimension of the soil grains, once swollen increase their volume, increasing soil porosity which guarantees a better roots oxygenation, as reported in the schematic representation in Figure 4.1.

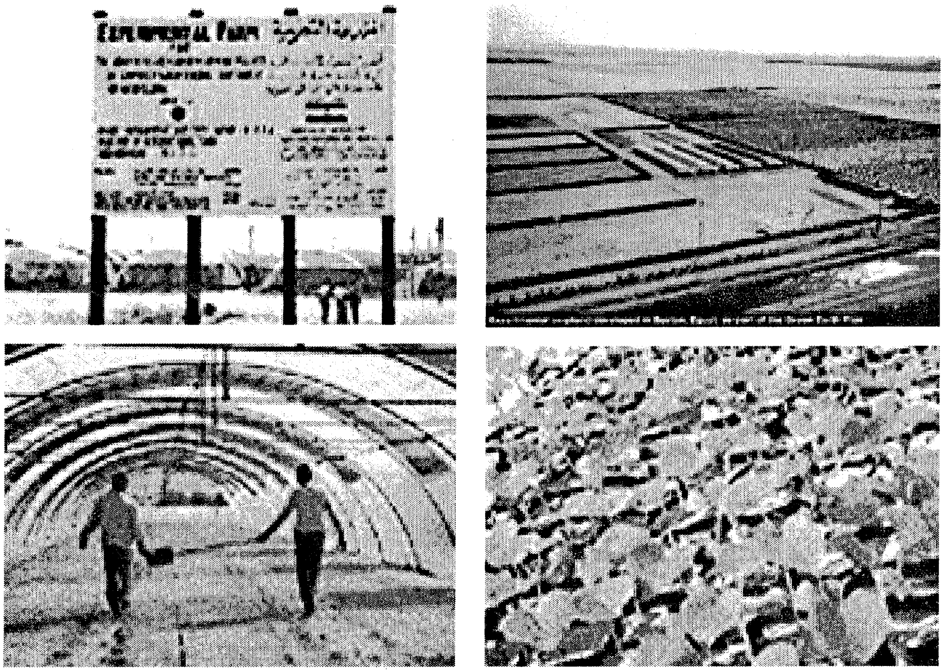
Figure 4.1: Dry and swollen hydrogel grain in the soil.



A project has been developed for the use of acrylamide based superabsorbents, and thus non biodegradable, as water release media to cultivations in arid regions.

In particular, the Japanese Ministry of International Commerce and Industry promoted a project for the development of intensive 'non water' cultivations in the Egyptian desert. The superabsorbent material was purchased by the Nippon Shokubai Co. Ltd, a multinational firm which is leader for the acrylamide based superabsorbents as absorbent core in baby diapers.

Figure 4.2: Some picture of the 'Greenhouse' in the Egyptian desert, where acrylamide based superabsorbents have been employed for water release to cultivations



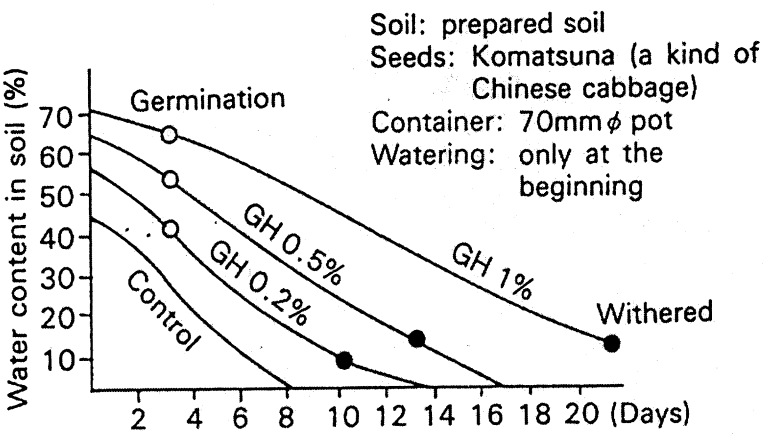
Source: (http://www.kubota.co.jp/eng/problem/earth/earth2.html)

Nippon Shokubai studies demonstrate that it is possibile to perform 'non water' cultivations in desert areas by means of superabsorbents. In particular, main advantages of such cultivation technique were as following: significant reduction of number of watering needed; lower amount of water to the cultivation; low mortality incidence of the plants; increase in plants growing rate; higher fertilizer retain in the soil.

In Figure 4.2 some pictures of the Egyptian 'Greenhouse' are reported. Both the Japanese Ministry of Commerce and Industry and the international firm producing the hydrogel cooperated with the Egyptian government, since the 1990, to this project called 'Green Earth project', and cultivation of both fruit and vegetables were successfully produced.

In Figure 4.3, moreover, humidity data of the soil are reported, in presence and in absence of hydrogel. In particular, the experiment has been carried out mixing the hydrogel (GH in the graph) to the soil, in the area surrounding the roots of a Komatsuna plant, in a weight percentage of 0.2, 0.5 and 1% respectively. Water has been added only once, and humidity in the soil has been monitored during time.

Figure 4.3: Soil humidity data obtained with and without adding the hydrogel to the soil, for a Komatsuna cultivation (Source : Nippon Shokubai Co. Ltd.)



A significant increase of humidity is observed in the graph increasing the hydrogel amount in the soil, even for long periods of time.

A second analysis has been carried out on a Coleus cultivation (Figure 4.4), and in particular plant high, weight and weight after plant desiccation have been monitored, both in cultivation performed with and without adding the hydrogel to the soil.

Figure 4.4: High and weight data for a Coleus cultivation, grown with and without hydrogel additino to the soil. (Nippon Shokubai Co. Ltd.)

		Control	GH 0.2%	GH 0.5%
Soil: volcanic ash	Height of plant (cm)	16.8	15.4	19.5
	Gross weight of plant (g)	7.8	14.7	14.5
	Dehydrated weight of plant (g)	1.2	1.8	2.7
Sandy soil	Height of plant (cm)	17.4	18.6	22.1
	Gross weight of plant (g)	12.7	18.3	23.9
	Dehydrated weight of plant (g)	3.3	4.6	5.8

It can be observed that, both in volcanic and sandy soils, plants grown in presence of hydrogel display height and weight significantly higher than those grown without adding hydrogel to the soil. This result has been attributed to the gradual water and nutrients release mechanism which takes place by means of this innovative cultivation technique.

However, a fundamental problem is present: materials used in this study are acrylamide based hydrogels, and thus not biodegradables and polluting for the soil. The high environmental impact and costs related to the hydrogel removal after each cultivation step prevent the use of these materials.

Moreover, acrylamide is an highly toxic monomer, and acrylamide based superabsorbents always have a non negligible amount of this component as unreacted residual inside the bulk. The release of such a molecule to the soil and, even worst, to the cultivation itself, would have a tremendous impact in poisoning the soil and cultivations.

The cellulose based hydrogel presented in this work have the same thermodynamic and morphological properties of the acrylamide based superabsorbent, and in addition is completely biodegradable in the soil, with even higher sorption properties. For this reason, it is expected to be the ideal candidate for the discussed application.

A study is in progress for the analysis of the performance of such a material on some Italian cultivations, and a plant has been designed for the massive production of such a material. One of the efforts of the research is to contain material production costs to value which are comparable with the non biodegradable product.

Conclusions

A novel technology has been set up for the agriculture in arid or desert regions, which allows a significant reduction of water amounts necessary for the cultivations and releases nutrients and fertilizers in pre-defined time and quantities.

This technology take advantage on the special sorption and desorption properties in water and water solution of a novel class of biodegradable superabsorbents, able to absorb more than 1,000 times their initial weight in water. The absorbed water is then released by a purely diffusion mechanism (without any convective mechanism, such as the one which takes place, for example, in sponges under compression), thus maintaining the optimal humidity level in the soil without any watering.

These materials are called hydrogels, and their synthesis has been studied, together with the correlation between material's chemical-physical parameters and its final sorption and desorption properties.

Three international patents have been performed on the material, and a project has been financed for experimental 'non water' cultivations in arid areas of the South of Italy.

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