GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(RESEARCH ARTICLE)

Check for updates

Hydrogel application in the germination and growth of *Zea mays* and *Solanum lycopersicum* seedlings

Domenico Prisa [1,*] and Giacomo Guerrini [2]

[1] *CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Research and Economics, Via dei Fiori 8, 51012 Pescia, PT, Italy.*
[2] *Bios Hydrogel, Via Trieste 31/A, 35121 Padova, PD, Italy.*

GSC Advanced Research and Reviews, 2022, 12(03), 026–032

Publication history: Received on 30 July 2022; revised on 01 September 2022; accepted on 03 September 2022

Article DOI: https://doi.org/10.30574/gscarr.2022.12.3.0233

Abstract

Research goal: This article presents the results of a research project aimed at demonstrating the effects and benefits of using an organic ingredient, hydrogel (Hydro Start), that can improve the germination and growth of *Zea mays* and *Solanum lycopersicum* seedlings.

Materials and Methods: Experiments began in April 2022 and were conducted in the greenhouses of CREA-OF in Pescia (PT) on seeded plants of *Zea mays* and *Solanum lycopersicum*. Seeds were placed in pots with different hydrogel capsules to determine if there were any effects on plant germination and growth. Agronomic analysis of the seeds and plants, microbiological analysis, and substrate evaluation were also conducted.

Results and Discussion: The experiment showed that the use of hydrogel can improve the quality and hardiness of the sown plants of *Zea mays* and *Solanum lycopersicum*. In general, the improvement in average germination time and plant growth was proportional to the number of hydrogel capsules placed in the substrate at the time of sowing; this also influenced the microbial colonisation of the soil. Studies show that the water retained in the hydrogel provides a water reservoir in the soil that can increase the efficiency of water uptake by plants. Mixing superabsorbent materials (hydrogels) with soils or growing media can significantly increase the water-holding capacity of the soil. This water is available to plants for a longer period of time, making them more resilient, especially when transplanting. In addition, incorporating hydrogels into the soil or growing media allows for improved germination, plant growth, and nutrient and water uptake.

Conclusions: Research shows that hydrogels can be used in a variety of ways due to their ability to retain water. These innovations can also ensure and promote plant survival under dry conditions. Further experiments are currently underway to evaluate hydrogels in tree species germination, transplanting, and acclimation.

Keywords: Plants growth; Microorganisms; Sustainable agriculture; Hydrogel; Rhizosphere

1. Introduction

Climate change, soil degradation, and urbanization lead to increased abiotic stress (water, heat, salt) faced by agriculture. The demand for water to irrigate crops is decreasing, while the need for food is increasing. Therefore, it is necessary to develop new techniques and technologies to maintain soil moisture long-term and increase crop resistance to drought [1, 2, 3]. One of the possible solutions to these environmental problems could be using hydrogels, crosslinked

* Corresponding author: Domenico Prisa
CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Research and Economics, Via dei Fiori 8, 51012 Pescia, PT, Italy.

materials that can absorb large amounts of water without dissolving and, in many cases, provide nutrients for plants [4]. Hydrogels are typically natural polymers containing proteins such as collagen and polysaccharides such as alginate [5, 6, 7]. Chemical polymerization processes usually produce the synthetic polymers that form hydrogels. A hydrogel is a single polymer molecule that is sandwiched between a liquid and a solid and can undergo drastic changes in volume as a result of certain external stimuli such as changes in temperature, pH or solvent [8,9]. The products used in agriculture are usually derived from the petroleum industry, can absorb their weight in water many times, and can be used in dry environments to improve the soil's water retention capacity [10,11]. Several past studies have shown that using hydrogels is very useful in water-scarce conditions to meet the water needs of plants. In these studies, these polymers were used at a dose of 2 g/kg and the water retention capacity of the sand was increased from 171% to 402%. Hydrogels reduce irrigation turnover by improving the water retention capacity of the soil, increasing the resistance of plants and reducing wilting [12, 13, 14]. Hydrogels can absorb moisture due to their particular swelling capacity, which can depend on the polymer's structure and external conditions [15]. The swelling process was studied by measuring the geometric dimensions and recording the volume of liquid remaining in the structure after absorption. The agricultural technology to use these water-absorbent polymers was developed in the late 1980s exclusively for agriculture. The goal was to improve the physical properties of the soil to [16, 17, 18]:

- Improve water use efficiency;
- Increase the water storage capacity of the soil;
- Reduce the frequency of irrigation;
- Stop the process of soil erosion;
- Increase crop performance, especially in extreme drought and salinity conditions.

Many studies indicate that synthetic fertilizers can be significantly reduced when hydrogels are used, improving crop yields and nutritional value. Sustainable practices would be especially beneficial in arid and semi-arid areas. In addition, the materials used to produce hydrogels are non-toxic and can be used safely in agricultural ecosystems [19, 20].

Objectives

This article presents the results of a research project aimed at demonstrating the effects and benefits of using an organic ingredient, Hydrogel (Hydro Start), that can improve the germination and growth of *Zea mays* and *Solanum lycopersicum* seedlings.

Figure 1 Detail of *Zea mays* and *Solanum lycopersicum* plants in greenhouse cultivation at the CREA in Pescia (PT) and placement of hydrogel capsules near the seed

2. Material and methods

The experiments, which started in April 2022, were conducted in the greenhouses of CREA-OF in Pescia (Pt), Tuscany, Italy (43°54'N 10°41'E) with *Zea mays* (Figure 1A,1B) and *Solanum lycopersicum* cv 'Cuore di Bue'. Seeds were placed in pots with a diameter of 12 cm; 16 sources per work were divided into four replicates of 4 seeds each.

The experimental groups were:

- Group without hydrogel (CTRL) (peat 90% + sand 10%), watered with water and previously fertilized with (1 kg m-3 COMPO Floranid Starter NPK 17-23-8, three months);
- Group with one hydrogel capsule near the seed (CP1) (peat 90% + sand 10%), watered with water;
- Group with two hydrogel capsules near the seed (CP2) (peat 90% + sand 10%), irrigated with water;
- Group with three hydrogel capsules near the seed (CP3) (peat 90% + sand 10%), irrigated with water.

The hydrogel (Hydro Start) had the following characteristics: 78% organic carbon; 5,8% nitrogen; 1% phosphorus; 1,2% potassium; 1% sulphur. The pH of the substrate was 6.8.

Plants were irrigated one time per day and grown for four months. Plants were irrigated with drip irrigation. Irrigation was activated by a timer whose program was adjusted weekly according to climatic conditions and leaching percentage. On 21 July 2022, plant height, vegetative weight, root weight, the number of germinated seeds, average germination time, the number of microorganisms in the substrate, and pH were determined.

2.1 Analysis methods

- pH: For pH measurement, 1 kg of the substrate was taken from each plant, and 50 g of the mixture was placed in a beaker containing 100 ml of distilled water. After 2 hours, the water was filtered and analyzed [21];
- Microbial count: direct determination of total microbial count by microscopy of cells contained in a known sample volume using counting chambers (Thoma chamber). The surface of the slide is etched with a grid of squares, with the area of each square known. Determination of viable microbial load after serial decimal dilutions, spatula seeding (1 ml) and plate counting after incubation [22];
- Analytical instruments: IP67 PHmeter HI99 series - Hanna instruments; Combined test kit for soil analysis - HI3896 - Hanna instruments; Microbial diversity of culturable cells [23].

2.2 Statistics

The experiment was carried out in a randomized complete block design. Collected data were analyzed by one-way ANOVA, using GLM univariate procedure, to assess significant ($P \leq 0.05$, 0.01 and 0.001) differences among treatments. Mean values were then separated by the LSD multiple-range tests ($P = 0.05$). Statistics and graphics were supported by the programs Costat (version 6.451) and Excel (Office 2010).

3. Results

Table 1 Evaluation of hydrogel use on the agronomic characters of *Zea mays*

Groups	Plant height (cm)	Vegetative weight (g)	Roots weight (g)	Germinated seeds (n°)	Germination time (days)	Substrate microbial Count (cfu/g)	pH substrate
CTRL	13,33 ^{b}	6,65 ^{c}	5,31 ^{b}	1,67 ^{b}	19,00 ^{a}	$1,30 \times 10^{2}$ ^{c}	6,76 ^{a}
CP1	20,00 ^{a}	7,40 ^{b}	6,01 ^{a}	3,33 ^{a}	16,33 ^{b}	$8,60 \times 10^{2}$ ^{b}	6,67 ^{b}
CP2	19,67 ^{a}	7,59 ^{ab}	6,08 ^{a}	3,00 ^{a}	15,33 ^{b}	$1,05 \times 10^{3}$ ^{a}	6,63 ^{b}
CP3	18,33 ^{a}	7,71 ^{a}	6,10 ^{a}	3,67 ^{a}	15,67 ^{b}	$1,08 \times 10^{3}$ ^{a}	6,60 ^{b}
ANOVA	*	***	***	*	***	***	*

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CT) control; (CP1) 1 capsule ;(CP2) 2 capsules; (CP3) 3 capsules

The experiment showed that the use of hydrogel could improve the quality and hardiness of the sown plants of *Zea mays* and *Solanum lycopersicum*. In general, the improvement in average germination time and plant growth was proportional to the number of hydrogel capsules placed in the substrate at the time of sowing; this also influenced the microbial colonization of the soil. In the soils where the number of hydrogel capsules (3 capsules) is higher, microbial colonization is also higher. In *Zea mays* (Table 1), all three experimental types (CP1, CP2, CP3) were significantly better than the control in terms of plant height (Fig. 2), vegetation and root weight, germination and germination time, and the number of microorganisms in the substrate. In addition, a significant decrease in pH was observed in these with hydrogel capsules.

The same tendency was observed in *Solanum lycopersicum* (Table 2), where the presence of the hydrogel in the substrate significantly improved germination and plant growth. Also in this case, the theses with two and three hydrogel capsules seem to perform better in terms of plant height, vegetative growth (Figure 3), seed germination and increased microbial colonization of the substrate. On the other hand, no differences in substrate pH were observed between the different theses, as was the case for *Zea mays*.

Table 2 Evaluation of hydrogel use on the agronomic characters of *Solanum lycopersicum*

Groups	Plant height (cm)	Vegetative weight (g)	Roots weight (g)	Germinated seeds (n°)	Germination time (days)	Substrate microbial Count (cfu/g)	pH substrate
CTRL	12,30 ^{b}	6,38 ^{d}	5,25 ^{b}	19,63 ^{b}	16,80 ^{a}	1,40 x $10^{2\,d}$	6,76 ^{a}
CP1	12,92 ^{a}	6,54 ^{c}	5,85 ^{a}	20,61 ^{ab}	14,40 ^{b}	7,77 x $10^{2\,c}$	6,72 ^{a}
CP2	12,91 ^{a}	6,91 ^{b}	5,87 ^{a}	24,22 ^{a}	14,00 ^{b}	9,51 x $10^{2\,b}$	6,78 ^{a}
CP3	13,04 ^{a}	6,96 ^{a}	5,95 ^{a}	20,44 ^{b}	14,80 ^{b}	1,01 x $10^{3\,a}$	6,72 ^{a}
ANOVA	***	***	***	Ns	***	***	Ns

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CT) control; (CP1) 1 capsule ;(CP2) 2 capsules; (CP3) 3 capsules

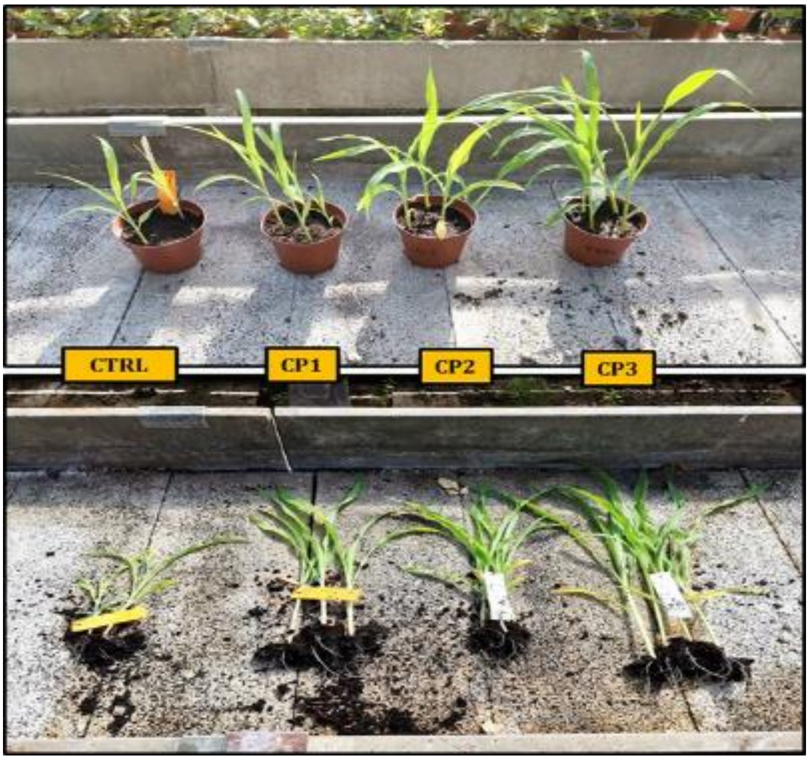

Figure 2 Effect of Hydrogel on the vegetative and radical growth of *Zea mays* plants

Figure 3 Effect of Hydrogel on the vegetative and radical growth of *Solanum lycopersicum* plants

4. Discussion

The application of hydrogels in agriculture was introduced to increase the water-holding capacity of soils and to promote the development and growth of plants in soils with extreme conditions, especially in the absence of water [24]. In addition, hydrophilic polymers have been used to ensure the transplantation of trees and shrubs in arid areas of the African and Australian continents; and to facilitate plant survival. The best results with these technologies were obtained in seed emergence and water retention in the soil with anionic polymers [25, 26, 27].

The effect of hydrogels on plant growth depends mainly on how they are used and applied to the soil, in growing media, or directly to the plants. For example, spraying hydrogels on the root zone is not sufficient. Better results were obtained when hydrogels were layered a few centimetres above the soil surface [28, 29]. This was also found in this experiment, where the hydrogel capsules were placed in the substrate together with the seeds. In this way, the properties of these products could be fully utilised, resulting in a significant improvement in the growth and quality of *Zea mays* and *Solanum lycopersicum* plants. When using hydrogels, several factors must be considered, such as the quality and type of hydrogel, the size of the granules, the type of application, and the type of plant grown.

Studies show that the water retained in the hydrogel provides a reservoir of water in the soil that can increase the efficiency of water uptake by plants. Mixing superabsorbent materials (hydrogels) with soils or growing media can significantly increase the soil water-holding capacity of the soil. This water is available to plants for a longer period of time, resulting in greater resilience, especially during transplanting [30, 31, 32]. In addition, the incorporation of hydrogels into the soil or growing medium improves germination, plant growth, and nutrient and water uptake [33,34, 35]. However, hydrogels can be degraded by environmental factors such as ultraviolet radiation, fertiliser salts, and freezing and thawing processes, which can break down the polymers into small fragments. In nature, there are microorganisms that can degrade polyacrylamide gels, especially bacteria (*Bacillus sphaericus* and *Acinetobacter spp.*) and fungi (*Phanerochaete chrysosporium* and *Pleurotus ostreatus*). These microorganisms dissolve the polymer and make it more susceptible to further degradation by other soil microbes. In the theses where hydrogels were present, the number of microorganisms present was significantly higher than in the control theses, probably because the polymers provide a greater water reserve to the substrate and can maintain conditions favourable to the microorganisms in the rhizosphere for a longer time, which has a positive effect on plant activity [21, 22].

5. Conclusion

Research shows that hydrogels have many uses due to their ability to bind water. Polymers can absorb up to 600 times their weight in water and alter the water capacity of the growing medium to promote the growth of plant species under water-stress conditions. These innovations can also ensure and promote plant survival under dry conditions. Further experiments are currently underway to evaluate hydrogels in tree species germination, transplanting and acclimation.

Compliance with ethical standards

Acknowledgments

The research is part of the project “HYDROPLANT”: Study on the application of Hydrogel in substrates for cultivating vegetable and ornamental plants''. Thanks to the company Bios Hydrogel Srl (Padova) for funding the project.

Disclosure of conflict of interest

The author declares no conflict of interest.

References

[1] Ahmad M and Verplancke H. Germination and biomass production as affected by salinity in Hydrogel treated sandy soil. Pakistan J. Forest., 1994, 44, 53–61.

[2] Akhter J, Mahmood K, Malik KA, Mardan A, Ahmad M and Iqbal, MM. Effects of hydrogel amendment on water storage of sandy loam and loam soils and seedling growth of barley, wheat and chickpea. Plant Soil and Environment, 2004, 50(10), 463-469.

[3] Asghari S, Abbasi F and Neyshabouri MR. Effects of soil conditioners on physical quality and bromide transport properties in a sandy loam soil. Biosystem Engineering, 2011, 109, 90-97.

[4] Baasiri M, Ryan J, Mucheik M and Harik SN. Soil application of a hydrogel conditioner in relation to moisture, irrigation frequency and crop growth. Communications in Soil Science and Plant Analysis, 1986, 17, 573-589.

[5] Bakass M, Mokhlisse A and Lallemant M. Absorption and desorption of liquid water by a superabsorbent polymer: Effect of polymer in the drying of the soil and the quality of certain plants. J Appl. Polym. Sci. 2002, 83, 234-243.

[6] Bearce BC and McCollum RW. A comparison of peat lite and noncomposted hardwood-bark mixes for use in pot and bedding-plant production and the effect of a hydrogel on their performance. Flor. Rev. 1977, 161, 21-23.

[7] Boartright JL, Balint DE, Mackay WA and Zajicek JM,. Incorporation of a hydrogel into annual landscape beds. Journal of Environmental Horticulture, 1997, 15, 37-40.

[8] Callaghan TV, Abdelnour H and Lindley DK. The environmental crisis in the Sudan: the effect of waterabsorbing synthetic polymers on tree germination and early survival. Journal of Arid Environments, 1988, 14, 301- 317.

[9] Callaghan TV, Lindley DK, Ali OM, Abdelnour H and Bacon PJ. 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 1989, 26, 663-672.

[10] Dehkordi KD. Effect of superabsorbent polymer on salt and drought resistance of eucalyptus globulus. Applied Ecology and Environmental Research, 2017, 15(4), 1791–1802.

[11] Demitri C, Del Sole R, Scalera F, Sannino A, Vasapollo G, Maffezzoli A, Ambrosio L and Nicolais L. Novel superabsorbent cellulose-based hydrogels crosslinked with citric acid. Journal of AppliedPolymer Science, 2008, 110, 2453–2460.

[12] Ekebafe LO, Ogbeifun DE and Okieimen FE. Polymer applications in agriculture. Biokemistri, 2011, 23(2), 81–89.

[13] El-Asmar J, Jaafar H and Bash I. Hydrogel banding improves plant, survival, and water use efficiency in two calcareous soils. Clean Soil Air Water, 2017, 47(7), 1700251.

[14] El-Hady OA, Tayel MY and Lofty AA. Super gel as a soil conditioner: its effect on plant growth, enzymes activity, water use efficiency and nutrient uptake. Acta Horticulturae, 1981, 119(22), 257–265.

[15] Gehring JM and Lewis AJ. Effect of Hydrogel on wilting and moisture stress of bedding plants. Journal of American Society of Horticultural Science, 1980, 105, 511-513.

[16] Gilbert C, Peter S, Wilson N, Edward M, Francis M and Sylvester K. Effects of Hydrogels on Soil Moisture and Growth of Leucaena Pallida in Semi Arid Zone of Kongelai, West Pokot County. Open Journal of Atmospheric and Climate Change, 2014, 1(2), 2374-3794.

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

[18] Huttermann A, Zommorodi M and Reise K. Addition of Hydrogels to Soil for Prolonging the Survival of Pinushalepensis Seedlings Subjected to Drought. Soil Tillage Research, 1999, 50, 295– 304.

[19] Ingram DL and Yeager TH. Effect of irrigation frequency and a water-absorbing polymer amendment on Ligustrum growth and moisture retention by a container medium. J. Environ. Hort., 1987, 5, 19–21.

[20] Mikkelsen RL. Using hydrogels to control nutrient release. Fertilizer Research, 1994, 38, 53-59.

[21] Prisa D. Beneficial interaction between algae and rhizobacteria in the cultivation and defense of potted succulent plants. EPRA International Journal of Agriculture and Rural Economic Research (ARER). 2022, 10(3), 18-26.

[22] Prisa D and Centomo G. Microbial processing of tannery waste for compost production in the growth and quality improvement of ornamental plants. GSC Advanced Research and Reviews, 2022, 12(01), 135–144.

[23] Prisa D. Natural acidifier application with effects on soil microbial activity in Swiss chard, Tuscany black cabbage and Tetragonia tetragonioides cultivation.EPRA International Journal of Agriculture and Rural Economic Research (ARER), 2022, 10(5), 25-33.

[24] Narjary B, Pramila A, Anupama S, Debashis C and Ravender S. Water availability in different soils in relation to hydrogel application. Geoderma, 2012, 187-188, 94-101.

[25] Orikiriza LJB, Agaba H, Tweheyo M, et al. Amending soils with hydrogels increases the biomass of nine tree species under non-water stress conditions. Clean-Soil Air Water, 2009, 37(8), 615–620.

[26] Ovalesha MA, Yadav B and Rai PK. Effects of polymer seed coating and seed treatment on plant growth, seed yield and quality of Cowpea (Vigna unguiculata). Journal of Pharmacognosy and Phytochemistry, 2017, 6(4), 106–109.

[27] Roy T, Kumar S, Chand L, Kadam DM, Bihari B, Shrimali SS et al. Impact of Pusa hydrogel application on yield and productivity of rainfed wheat in North West Himalayan region. Current Science, 2019, 116(7), 10-19.

[28] Save R, Perv N, Marfa O and Serrano L. The effect of hydrophilic polymer on plant and water status and survival of pine seedlings. HortTechnology, 1995, 5, 141- 143.

[29] Singh A, Sarkar DJ, Singh AK, Parsad R, Kumar A and Parmar BS. Studies on novel nanosuperabsorbent composites: Swelling behavior in different environments and effect on water absorption and retention properties of sandy loam soil and soilĞless medium. Journal of Applied Polymer Science, 2011, 120(3), 1448- 1458.

[30] Specht A and Harvey-Jones J. Improving water delivery to the roots of recently transplanted seedling trees: the use of hydrogels to reduce leaf and hasten root establishment. Forest Research, 2000, 1, 117-123.

[31] Viero PWM, Little KM and Oscroft DG. The effect of a soil-amended hydrogel on the establishment of Eucalyptus grandis x E. camaldulensis clone grown on the sandy soils of Zululand. South African Forestry Journal 2000, 188, 21-28.

[32] Wallace A and Wallace GA. Effect of polymeric soil conditioners on emergence of tomato seedlings. Soil Science, 1986, 141, 321-323.

[33] Wang YT and Gregg LL. Hydrophilic polymers-their response to amendments and effect on properties of a soilless potting mix. Journal of the American Society for Horticultural Science, 1990, 115, 943-948.

[34] Woodhouse JM and Johnson MS. The effect of a gel forming polymer on seed germination and establishment. J. Arid Environ., 1991, 20, 375–380.

[35] Zohuriaan-Mehr MJ and Kabiri K. Superabsorbent polymer materials: a review. IranianPolymer Journal, 2008, 17(6), 451.