

New bio-based super-absorbent hydrogels, a game-changing tool for organic vineyards water management and adaptation to drought

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Abstract

Hydrogels are soil-conditioning materials capable of absorbing substantial amounts of water relative to their weight. Their use in agriculture is rapidly expanding and new bio-based hydrogels allowed in organic agriculture are now available, but their effects on grapevines at transplanting has until now not been explored. This study compared the localised root-zone application to soil of a potassium polyacrylate hydrogel (SH1) and an organic hydrogel (SH2) at vine transplanting, with an untreated control (C) in two experiments: one on potted vines under semi-controlled conditions and the other in a newly established rainfed vineyard. Both SH1 and SH2 increased soil field capacity and maximum available water. In the potted vines, they improved water status under drought conditions, delaying the decline of stem water potential (+ 0.25 MPa on the last day before rewatering) and enhancing leaf gas exchange (+ 9 and + 8 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for SH1 and SH2, respectively, as compared to C). By the end of the second season after transplanting, SH1 and SH2-treated vines exhibited greater leaf area, higher yield (+ 29 % and + 26 % relative to C, respectively), and a lower leaf-to-fruit ratio, resulting in reduced fruit sugars (-2.0 and -2.2 °Brix respectively) and anthocyanin levels. In the field, shoot growth and final leaf area after two years were higher in SH1- and SH2-treated vines (+ 25 %). SH1 accelerated the transition to a productive stage, while SH2 reduced the number of vines requiring two-nodes pruning. Our findings indicate that bio-based hydrogels are promising tools for organic vineyard water management. Their incorporation at transplanting could help shorten unproductive stages and accelerate full crop development.

Keywords: Water-stress, Climate change, Transplanting, Grapevine, Biofertilizers

Introduction

Superabsorbent hydrogels are materials capable of taking up and retaining large quantities of water or aqueous solutions relative to their own mass. They consist of a three-dimensional network of polymer chains enriched with hydrophilic functional groups (Guilherme et al., 2015). Depending on their chemical composition, these materials can absorb between 9 and 400 times their dry weight in water (up to 400 mL/g). Recent advancements, however, have led to the development of new acrylamide-free hydrogels, some of which are fully derived from renewable organic sources such as lignocellulosic or starch-based byproducts, making them suitable also for organic farming and cost-effective.

The aim of this study was to assess how the localized application of an organic superabsorbent hydrogels to the root zone at transplanting affects soil water dynamics and grapevine physiological responses, compared to a synthetic one and to untreated controls. We hypothesized that modifying soil hydrology in this way could enhance vine water status and vegetative growth, thereby promoting faster canopy establishment on trellis wires and reducing the duration of the vineyard's unproductive phase. To test this, we employed a multidisciplinary approach combining grapevine physiology experiments conducted under semi-controlled conditions and subsequent field trials.

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Material and Methods

In this study, the three following treatments were compared: an untreated control (C), the incorporation of a potassium polyacrylate-based hydrogel into the soil (SH1), and the incorporation of a ligno-cellulosic hydrogel (permitted in organic agriculture) into the soil (SH2). Two experiments were conducted, the first one, on potted (55L) vines cv. Sangiovese subjected to a progressive water deficit for two seasons (2023 and 2024), the second one on field-grown cv. Sauvignon blanc vines in the Colli Piacentini wine district. In both trials, hydrogels were applied at transplanting (April 2023) at the doses of 30 g/plant for SH1 and 100 g/plant in SH2, in a way to ensure a uniform maximum water absorption by the two hydrogels used, in accordance with Frioni et al. (2024). In pots, stem water potential (Ψ) was periodically measured with a Scholander pressure chamber (Soilmoisture, Goleta CA, USA), leaf gas exchange parameters were measured with an ADC LC-sd infrared gas-exchange analyzer (ADC Bioscientific, Hoddesdon, UK). In both the experiments, vegetative growth was assessed in winter, and yield at the first productive season was quantified.

Results and Discussion

In potted vines, under full irrigation, midday stem Ψ , indicator of plant water status, remained comparable between treatments in both years (Fig. 1A and 1B). In 2023, after the reduction of irrigation to 50%ET, stem Ψ decreased in C vines passing from -0.43MPa to -0.64 MPa (Fig. 1A), while in SH1 and SH2 it remained significantly higher (-0.31MPa on DOY212 and -0.49MPa on DOY214, pooling SH treatments). When irrigation was fully suspended, in all treatments stem Ψ dramatically decreased, but in SH1 and SH2 stem Ψ was again higher than in C vines (-1.25MPa pooling SH1 and SH2, vs -1.5 MPa in C). Leaf photosynthetic rates paralleled vine water status in both seasons, with SH1 and SH2 showing consistently higher leaf photosynthesis than C under reduced or null irrigation.

SH1 and SH2 had significantly higher vine yield than C (+55% and +59%, respectively), due to higher shoot fruitfulness (+2 clusters/vine), cluster weight (+29% in SH1 and +31% in SH2), and berry mass (+0.3g/berry) (Table 1). SH1 and SH2 showed lower TSS at harvest than C (-2.0 and -2.2°Brix respectively).

In field, at the end of 2024, 34.1% of C vine were still in non-productive stages, while 84% of the SH1 vines had reached their productive stages and none of the vines had to be pruned back to two nodes. A significantly lower number of SH2 vines had to be pruned back to two-nodes (4.4%), as compared to C (9.1%).

Table 1: Yield and fruit composition in 2024 in potted vines cv. Sangiovese according to pre-planting soil application of Superabsorbent Hydrogels. C: Untreated control; SH1: soil incorporation of a potassium polyacrylate hydrogel; SH2: soil incorporation of a lignin sulfonate hydrogel.

Treatment	Yield (kg/vine)	Cluster weight	Berry weight	TSS	pH	TA
C	2.2 b	216 b	2.1 b	20.9 a	3.30	6.2
SH1	3.4 a	283 a	2.4 a	18.9 b	3.30	6.5
SH2	3.5 a	279 a	2.4 a	18.7 b	3.29	6.5
<i>t</i>	***	***	**	***	ns	ns

TSS= Total Soluble solids; TA= Titratable Acidity.

*, ** and *** indicate significant difference per $P < 0.05$, 0.01 and 0.005 , respectively. ns= no difference.

Different letters within columns indicate significant differences between treatments per $P < 0.05$ (SNK test).

In a near future, the soil application of hydrogels could represent a game-changing tool in the adaptation of agriculture to climate change. Our work demonstrates that new bio-based hydrogels can be used to locally control soil water availability and improve vines tolerance

to water deficit after transplanting, thus reducing vine mortality and accelerating the transition towards full crop production. Although studies in relation to different soils and pedoclimatic conditions are needed, this work paves the way for the implementation of the technique in organic vineyards.

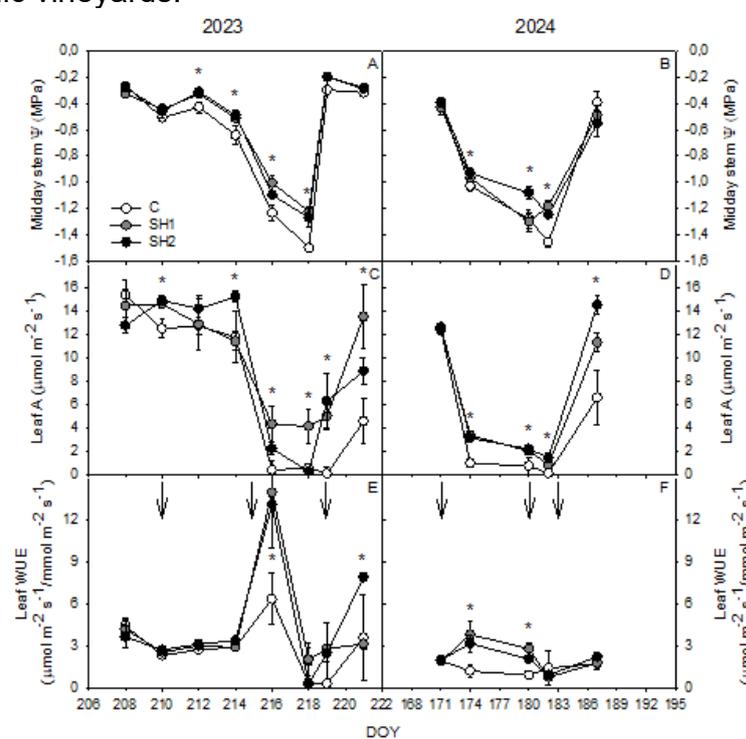


Figure 1: Seasonal trend of midday stem water potential Ψ (panels A and B), leaf photosynthesis (A) (panels C and D) and leaf water use efficiency (WUE) (panels E and F) in potted vines cv. Sangiovese according to pre-planting soil application of Superabsorbent Hydrogels. C: Untreated control; SH1: soil incorporation of a potassium polyacrylate hydrogel 30 g/plant; SH2: soil incorporation of a lignin sulfonate hydrogel 100 g/plant. Asterisks indicate significant difference between treatments per $P < 0.05$. From left to right, arrows in panels E and F indicate the day of reduction of irrigation to 50%ET, the day water supply was fully suspended, and the day of rewatering, in 2023 and 2024.

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