

Calcium Inhibition of Polyacrylamide Gel Hydration Is Partially Reversible by Potassium

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Abstract. Hydration of a commercial hydrophilic polyacrylamide gel in 20 meq $\text{Ca}(\text{NO}_3)_2$ /liter was reduced to <10% of the maximum hydration in deionized water. Repeated soaking with deionized water to remove soluble salts restored hydration to \approx 30% of maximum. Incorporating KNO_3 at concentrations ranging from 5 to 40 meq·liter⁻¹ with the $\text{Ca}(\text{NO}_3)_2$ in the hydration solution partially reversed the Ca^{2+} inhibition of hydration following repeated soaking. Potential hydrogel hydration increased to 50% of maximum with 40 meq K/liter. Potassium nitrate supplied separately following hydration in $\text{Ca}(\text{NO}_3)_2$ was much more effective at reversing Ca^{2+} inhibition of hydrogel hydration than joint application. Potential hydrogel hydration (following repeated soaking) was doubled after treatment with 5 meq KNO_3 /liter and reached 77% of maximum at 40 meq KNO_3 /liter.

Hydrophilic polyacrylamide gels (hydrogels) are marketed as amendments to increase the water-holding capacity of container media and field soils, based on their ability to absorb up to 1500 times their weight in water (Johnson, 1984). The cross-linked polyacrylamide hydrogels commonly available in the horticultural trade are capable of absorbing >400 ml of water per gram of hydrogel. The presence of salts in solution, however, severely restricts hydrogel hydration (Bowman et al., 1990; Foster and Keever, 1990; James and Richards, 1986; Lamont and O'Connell, 1987; Wang and Gregg, 1990). Solutions containing salts of the monovalent cations K^+ and NH_4^+ or the divalent cations Ca^{2+} and Mg^{2+} , at 20 meq·liter⁻¹, reduced hydrogel hydration by >75% and 90% of maximum, respectively (Bowman et al., 1990). The inhibition of hydration caused by KNO_3 was completely reversed by rinsing the hydrogels with deionized water (DI), whereas the inhibition caused by $\text{Ca}(\text{NO}_3)_2$ was only partially reversible. We found no reports of methods by which the Ca^{2+} inhibition of hydrogel hydration might be removed. We report here the results of two

experiments examining the effects of K^+ on a calcium-inhibited hydrogel.

Experiment 1 examined the effect on hydrogel hydration of K^+ supplied in solution with Ca^{2+} . Samples (1 g) of a commercial polyacrylamide hydrogel (Broadleaf P-4, Broadleaf Industries, San Diego, Calif.), with a particle size of 1 to 2 mm, were each added to either 1 liter of DI or 1 liter of 20 meq $\text{Ca}(\text{NO}_3)_2$ /liter, plus KNO_3 at 0, 5, 10, 20, or 40 meq·liter⁻¹, with three replicates per treatment. After 24 h, the hydrated hydrogels were collected on a fine mesh screen and the excess solution was removed by blotting the bottom of the screen with a moist sponge. After weighing the samples, each was transferred to 1 liter of DI for 24 h, then collected and reweighed. The samples were transferred daily for 3 days to fresh DI and reweighed to estimate the maximum potential hydration of the hydrogels.

Experiment 2 examined the ability of K^+ to reverse the calcium inhibition of hydrogel hydration when the KNO_3 solution was supplied after hydration of the hydrogel in a solution of $\text{Ca}(\text{NO}_3)_2$. Samples (1 g) of the hydrogel were hydrated for 24 h in 1 liter of 20 meq $\text{Ca}(\text{NO}_3)_2$ /liter. The samples were then collected, weighed, and transferred to 1-liter solutions of KNO_3 at 0, 5, 10, 20, and 40 meq·liter⁻¹. The hydrogel samples were weighed again after 24 h, then transferred to 1 liter of DI. As in Expt. 1, this

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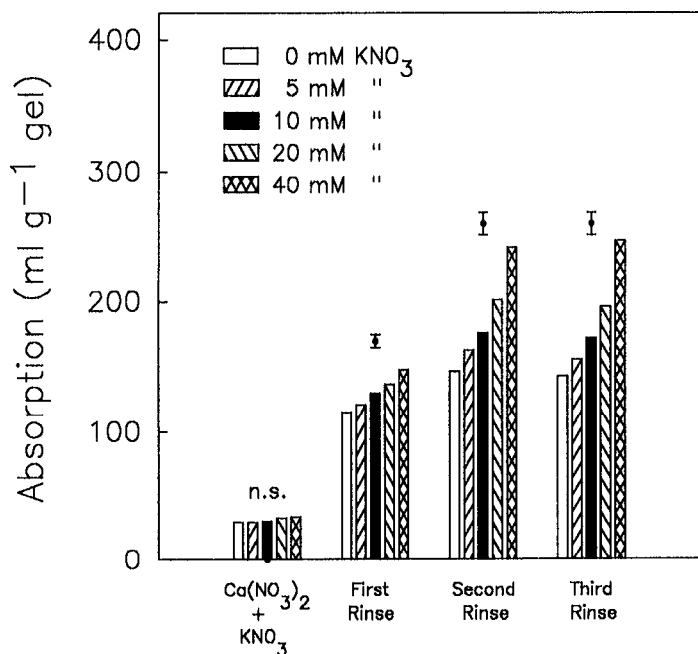


Fig. 1. The effect of KNO₃, supplied with Ca(NO₃)₂, in the hydrating solution, on the hydration potential of a polyacrylamide hydrogel (Expt. 1). Vertical bars represent LSD at $P = 0.05$ ($n = 3$).

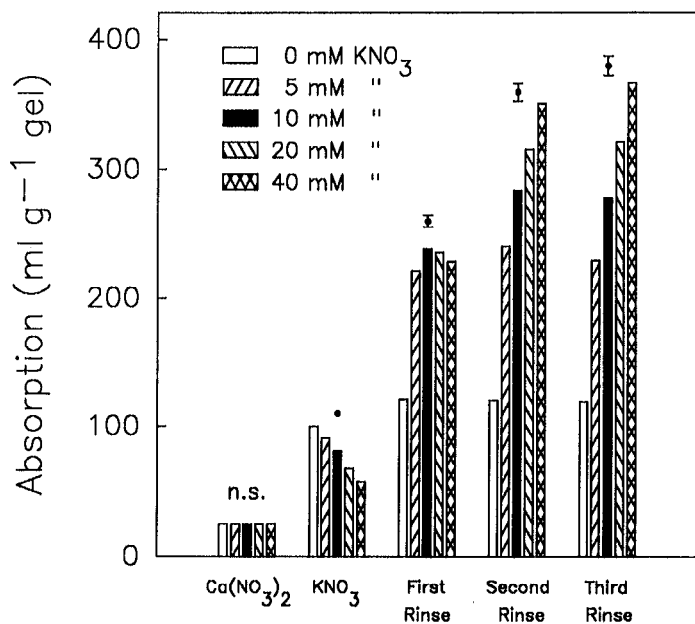


Fig. 2. The effect of KNO₃, supplied after gels were hydrated in Ca(NO₃)₂, on the hydration potential of a polyacrylamide hydrogel (Expt. 2). Vertical bars represent LSD at $P = 0.05$ ($n = 3$).

transfer to DI and reweighing was repeated daily for 3 days.

After a 24-h soaking in DI, the hydrogel had absorbed water at 420 ml·g⁻¹, whereas it absorbed only 30 ml·g⁻¹ in 20 meq Ca(NO₃)₂/liter (Fig. 1). Sequential soakings in DI increased hydration to ≈ 30% of maximum. Inclusion of KNO₃ with Ca(NO₃)₂ in the hydration solution had no additional effect on the initial hydration of the hydrogel, but did provide some protection from calcium inhibition of hydration following soaking in DI. Hydration after the DI soaks increased linearly with K⁺ concentration, from ≈ 150 ml·g⁻¹ hydrogel in 20 meq Ca(NO₃)₂/liter to 250 ml·g⁻¹ hydrogel in 20 meq·liter⁻¹ Ca(NO₃)₂/liter plus 40 meq KNO₃/liter.

Potassium ion was considerably more effective at restoring the hydration capacity of the hydrogel when it was supplied subsequent to the calcium salt (Fig. 2). Treatment with K⁺ at 5 meq·liter⁻¹ followed by soaking in DI doubled hydrogel hydration compared with the DI-soaked Ca(NO₃)₂ control. Treatment with 40 meq K⁺/liter followed by repeated soaking in DI, restored hydration of the hydrogel to 77% of maximum. Since the effect of KNO₃ (in the absence of Ca²⁺) is completely reversible by rinsing in DI (Bowman et al., 1990), the remaining inhibition observed here could be attributed to Ca²⁺ retained by the hydrogel.

These results underscore the importance of monovalent-divalent cation interactions

in modulating polyacrylamide gel hydration. Supplying K⁺ in solution together with Ca²⁺ resulted in only a moderate increase in the hydration of the hydrogel after repeated soaking. In Expt. 1, where the hydrogel was hydrated in solutions of Ca(NO₃)₂ plus KNO₃, the improvement in hydration with increasing KNO₃ concentration is probably due to the competition between K⁺ and Ca²⁺ for cation exchange sites in the hydrogel. In contrast, the large increases in hydration observed in Expt. 2 are probably the result of K⁺ displacing Ca²⁺ on the hydrogel's cation exchange sites. Calcium would then be free to diffuse out of the hydrogel matrix. Eventually, an equilibrium would be reached between the activities of Ca²⁺ and K⁺ in solution and exchangeable Ca²⁺ and K⁺ on the cation exchange sites. The greater effectiveness of KNO₃ when supplied subsequent to hydration of the hydrogel in Ca(NO₃)₂ was most likely a consequence of the much lower Ca²⁺ concentration in solution at equilibrium. Whether KNO₃ was supplied together with Ca(NO₃)₂ or afterwards, its effect on calcium-inhibited hydrogel was evident only after repeated soaking in DI.

Based on these results, the potential horticultural benefits of hydrogel as a soil amendment might be enhanced by leaching gel-amended soils with water, or leaching first with a solution containing a potassium salt, followed by leaching with water. However, the application of such a practice in commercial horticulture may be limited. Most container media have a reservoir of calcium present in the solid phase, typically as calcium carbonate or dolomitic limestone. For such media, it would be extremely difficult to remove sufficient Ca²⁺ from the soil solution to permit rehydration of the hydrogel. Additionally, other container-soil amendments, such as Micromax, strongly inhibit hydrogel hydration (Foster and Keever, 1990), so it might be necessary to remove or exclude these as well. Finally, exhaustive leaching would be practical only at the end of the crop production cycle, when removal of the plant's nutrient supply may be unimportant.

We conclude that the inhibition of hydrogel hydration by calcium salts is partially reversible by application of solutions containing potassium salts, particularly when they are added after removal of Ca²⁺ from the solution bathing the hydrogel, and then only when followed by repeated soaking to remove soluble salts from the hydrogel. The need for thorough leaching of the hydrogel to restore hydration capacity may limit the practical application of this procedure in current horticultural production.

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