THE EFFECTIVENESS OF HYDROGELS IN CONTAINER PLANT PRODUCTION IS REDUCED BY FERTILIZER SALTS

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Hydrophilic polymers first became available to the nursery trade in the early 1970s, and interest in their application to container plant production has waxed and waned more than once since then. These amendments are receiving a lot of attention once again as suppliers promote the purported advantages of hydrophilic polymer addition: decreased water use, which is particularly attractive during a drought, and less product loss from infrequent watering, which is more important now that large retail chains are major outlets for nursery products. Unfortunately, growers seeking information about the effectiveness of hydrophilic polymers have encounter conflicting information from salesmen and horticulturists alike.

It has been suggested that hydrogels may be useful as a soil amendment to improve water-holding capacity because they can hold up to 1500 times their weight in water. There have been several reports by researchers indicating benefits from hydrogels. Additions of gel to a peat:perlite mix reduced water stress and increased time to wilt in zinnias. In some other studies, researchers found that the frequency and total amount of irrigation could be reduced by incorporating gels in the potting mix. However, other reports have shown little or no benefit from gels added to potting mixes at recommended rates, and a recent study of gel effects on water stress in tall fescue concluded that gels were not effective unless added at more than 80 times the recommended rate.

The absence of benefit from gels in some of these studies may be due to the inhibition of gel hydration by salts dissolved in the irrigation water or fertilizers. For example, growth of *Ligustrum lucidum* in a gel-amended mix was negatively affected by increased fertilizer rates. In addition, there have been several reports describing the inhibition of gel hydration in the presence of salt solutions.

These results show that fertilizer solutions, such as those used in the greenhouse and container nursery industry, might restrict the potential benefit of hydrogel as an amendment. We have investigated the effects of various fertilizer salts, at concentrations commonly used in container plant production, on water absorption by three polyacrylamide hydrophilic gels. In addition, we examined the effect of fertilizer salts and gel amendment on the physical properties of three typical container media: a redwood sawdust:sand (2:1 by volume) mix typical of those used in woody plant nurseries, a redwood sawdust:peat:sand (1:1:1 by volume) mix typical of a "heavy" greenhouse potting mix, and a peat:perlite (2:1 by volume) mix typical of a "light" greenhouse potting mix. Finally, we report the effects of gel addition on the growth and time to wilt of potted chrysanthemums.

Effect of fertilizer salts on water absorption by gels. Dry gels were allowed to absorb solutions of several commonly-used fertilizers for 24 hours, after which the excess solution was removed and the hydrated gels were weighed to determine moisture absorbed. Fertilizer salts substantially reduced absorption by the gels (Fig. 1). At a concentration of 20 meq l^{-1}, which is typically found in many commercial fertilizer solutions, the gels absorbed only 1/4 or less of the amount absorbed in deionized water. Absorption in fertilizer solutions containing 20 meq l^{-1} of either calcium (Ca^{2+}) or magnesium (Mg^{2+}) was reduced to less than 10% of that in deionized water. In con-

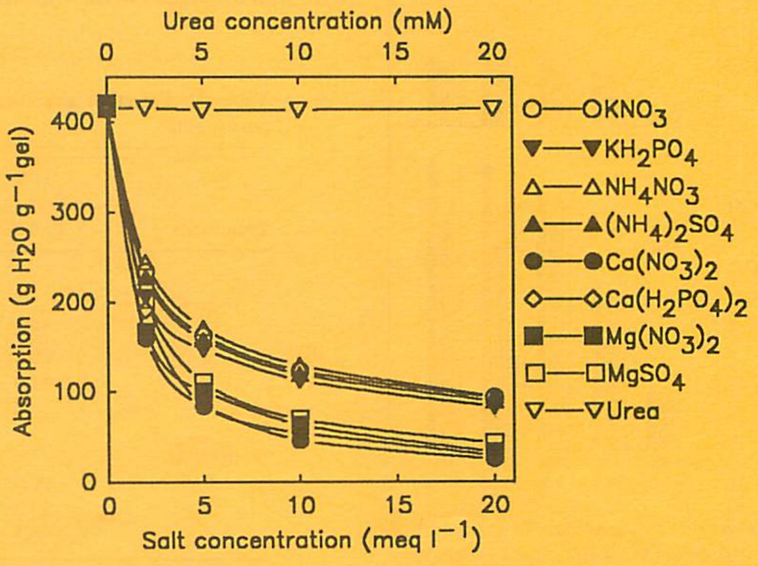

Fig. 1. Effect of fertilizers on hydration of a hydrophilic polyacrylamide gel. The upper group of curves shows the response to monovalent cations and the upper group shows the response to divalent cations.

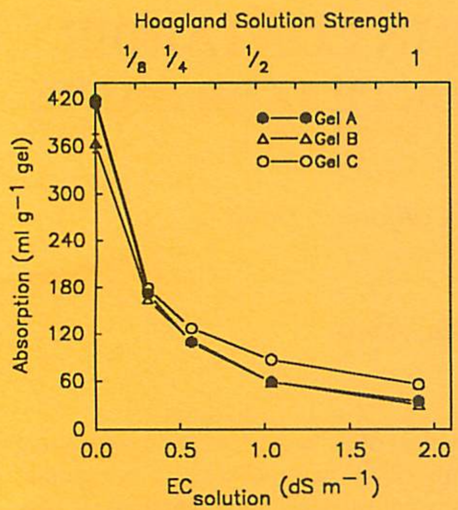

Fig. 2. Effect of a complete Hoagland's nutrient solution on gel hydration.

Table 1. Physical properties of gel-amended redwood sawdust:sand (2:1) medium, irrigated with deionized water or a fertilizer solution.

Treatment	Total Porosity[z] (vol %)	Air-filled Porosity (vol %)	Container Capacity (vol %)	H_2O Content at 100 cm (vol %)	Bulk Density (g cm^{-3})
Control					
- Fertilizer	74.6 c[y]	21.1 a	53.5 cd	19.1 a	.60 a
+ Fertilizer	74.4 c	19.8 a	54.6 c	18.9 a	.61 a
1xGel (2 lb/cu yd)					
- Fertilizer	77.4 b	17.6 b	59.8 b	37.3 d	.54 b
+ Fertilizer	74.3 c	21.5 a	52.8 d	21.9 a	.61 a
2xGel (4 lb/cu yd)					
- Fertilizer	78.5 a	16.8 b	61.7 a	29.7 c	.51 c
+ Fertilizer	75.0 c	20.6 a	54.5 cd	26.4 b	.59 a

zData are means of three replications.

yMeans followed by the same letter within a column are not significantly different, 0.05 level.

trast, the uncharged solute, urea, did not reduce absorption at any concentration tested. When gels were allowed to absorb a complete nutrient solution (Hoagland's solution), the reduction in absorption was almost identical to that in the presence in Ca^{2+} or Mg^{2+} at similar concentrations (Fig. 2).

To determine whether the water absorption of salt-inhibited gels could be restored by clear irrigation, we examined the permanence of the salt effect on gel hydration. When gels which had been hydrated in 20 meq l^{-1} KNO_3 were rinsed repeatedly in deionized water, absorption after the third rinse was greater than the maximum following hydration in deionized water (Fig. 3). However, absorption by gels which had been hydrated in $Ca(NO_3)_2$ could be restored to only 28% of full absorption capacity, even after four rinses.

Effect of fertilizer salts and gel amendment on the physical properties of a redwood sawdust:sand potting mix. A container mix typical of those used in the woody nursery industry was prepared from redwood sawdust and sand mixed in a ratio of 2:1. The mix was divided in two, with half amended with dolomite, superphosphate, potassium nitrate, and Micromax®. The other half received no chemical amendments. A hydrophilic gel was mixed into both the amended and unamended mixes at rates of 0, 2 (manufacturer's recommended rate), and 4 lbs per cubic yard. Columns 13 cm deep (between the height of a 6" pot and a gallon container) were filled with each of the mixes. The chemically-amended mix was irrigated with a fertilizer solution and the unamended mix was irrigated with deionized water, after which the physical properties of the mixes were determined by standard methods. Addition of gel altered the physical properties of the mix that received no fertilizers (Table 1). Total porosity and container capacity increased slightly, and air-filled

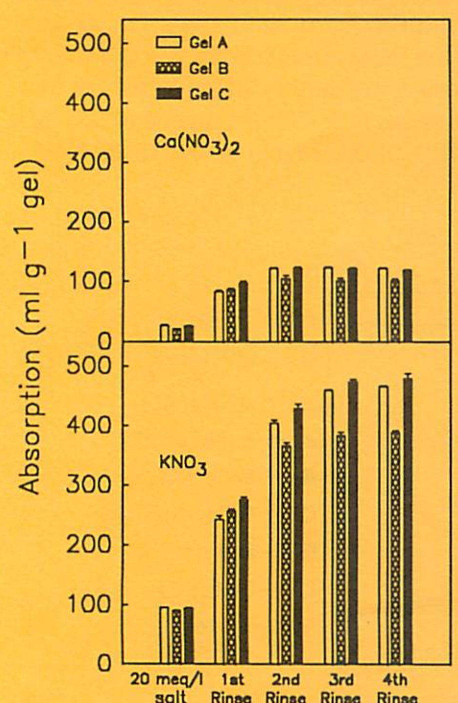

Fig. 3. Reversal of salt-inhibition of gel hydration by sequential deionized water rinses. Gels were initially hydrated in 20 meq l^{-1} $Ca(NO_3)_2$ (upper graph) or KNO_3 (lower graph).

Table 2. Effect of gel amendment on the physical properties of U.C. mix and peat:perlite.

Treatment	Total Porosity (vol %)	Air-filled Porosity (vol %)	Container Capacity (vol %)	Bulk Density (g cm^{-3})	Available water (vol %)
		UC Mix			
lb/cu yd					
0	78.6	12.7	65.9	0.50	53.0
2	80.5	12.2	68.3	0.45	54.9
4	81.0	14.5	66.5	0.46	54.4
		Peat:Perlite			
lb/cu yd					
0	92.9	29.3	63.6	0.14	53.0
2	93.3	27.0	66.3	0.13	55.4
4	93.5	22.0	71.5	0.13	54.9

Table 3. Effect of hydrophilic gel amendment on days to wilting of chrysanthemum kept in a greenhouse or in simulated supermarket conditions. Plants were irrigated to container capacity with Hoagland's solution, then water was withheld until shoot tips wilted.

Rate (lb/cu yd)	UC Mix	Peat-Perlite
	Greenhouse	
0	1.12	1.13
2	1.15	1.13
4	1.18	1.16
	Supermarket	
0	2.95	2.96
2	3.00	2.98
4	3.07	3.05

Means within a treatment group (greenhouse or supermarket) were not significantly different (P=0.05).

porosity decreased slightly with gel additions. When fertilizers were present, however, gels did not affect total or air-filled porosities. The amount of water held at 100 cm tension increased substantially with gel addition in the absence of fertilizers. In contrast, there was little or no increase in the presence of fertilizers.

Effect of gel addition on the physical properties of two greenhouse potting mixes. Two greenhouse potting mixes were prepared, one a U.C. mix containing sphagnum peat, redwood sawdust, and sand in equal volumes, and the other containing sphagnum peat and perlite mixed in a ration of 2:1. Both received standard chemical amendments (dolomite, calcium carbonate, superphosphate, potassium nitrate, and Micromax®) and 0, 2 (manufacturer's recommended rate), or 4 lbs per cubic yard of a hydrophilic gel. The mixes were wetted with a fertilizer solution to allow the gels to hydrate, then columns 12 cm deep (typical of the height of a mix in a 6" pot) were filled with each of the mixes and the physical properties were determined. The physical properties of the U.C. mix were not significantly affected by gel addition, whereas gel addition to the peat:perlite mix increased the container capacity and decreased the air-filled porosity (Table 2).

Effect of gel addition on available water and on time to wilt and yield of chrysanthemum. Rooted cuttings of 'Bright Golden Anne' chrysanthemum were planted, three cuttings per pot, in 6" pots containing either U.C. mix or peat:perlite and 0, 2, or 4 lbs per cubic yard of a hydrophilic gel. The plants were watered as needed with a complete nutrient solution and grown under vegetative conditions, without growth regulator treatment, for 6 weeks. At the end of the sixth week, a tensiometer was placed in each container. The pots were irrigated to container capacity, then irrigation was withheld until the shoot tips began to wilt. The pots were then leached repeatedly with deionized water, moved to a room which simulated supermarket conditions, and allowed to wilt again. Soil moisture tension and water loss from the mixes was measured until wilt occurred. Gel addition did not affect the amount of available water in either mix (Table 2) and did not modify the moisture release of the mixes (Fig. 4). Similarly, the time to wilt in the greenhouse or the keeping room was unaffected by gel addition (Table 3), and the crop yield was similar in each treatment (Table 4).

Conclusions. The results presented here indicate that fertilizer salts dramatically reduce absorption by hydrophilic polyacrylamide gels. Divalent cations (Ca^{2+} and Mg^{2+}) dominate the effect of fertilizers on gel hydration. These ions may "lock" the polymer in place, restricting expansion (and thus water absorption). Clear watering does not overcome the inhibition of absorption caused by fertilizers containing calcium or magnesium.

Table 4. Effect of hydrophilic gel amendment on fresh weight (g) of chrysyanthemum.

Rate (lb/cu yd)	UC Mix	Peat-Perlite
0	317	315
2	306	314
4	297	292

Means were not significantly different (P=0.05).

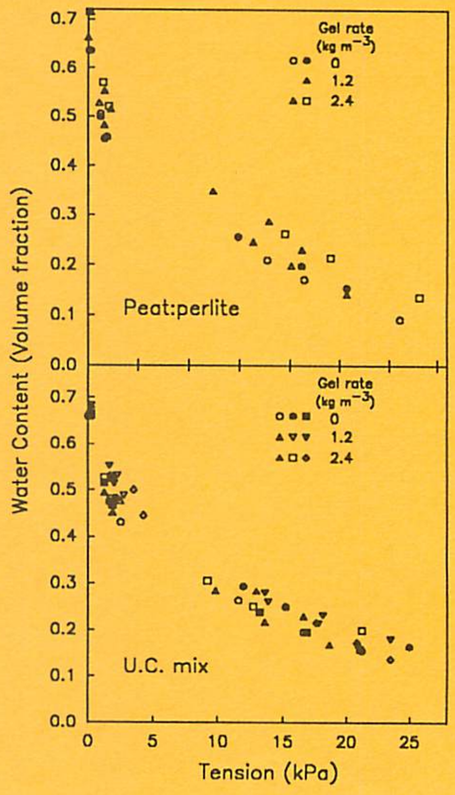

Fig. 4. Effect of gel amendment on the moisture release of U.C. mix and peat:perlite.

In the absence of fertilizer salts, gel addition altered the physical properties of the redwood sawdust:sand mix. In that mix there was a higher moisture content at 100 cm soil moisture tension when gel was present, indicating that a substantial amount of gel-absorbed water is retained while the bulk of the potting mix dries. However, this increase in moisture content occurred only in the absence of fertilizer salts. Since commercial greenhouse and nursery production depends on high fertility, it is unlikely that gel additions would improve the moisture holding capacity, yield, or time to wilt under most nursery conditions.

Acknowledgement. The authors gratefully acknowledge the skillful technical assistance of Kendra West.