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# Hydrophilic Polymers—Their Response to Soil Amendments and Effect on Properties of a Soilless Potting Mix

**Yin-Tung Wang**[1] **and Lori L. Gregg**[2]
*Texas A&M University Agricultural Research and Extension Center, 2415 East Highway 83,*
*-Weslaco, TX 78596*

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*Abstract.* **The levels of hydration of several hydrophilic polymers (hydrogels) varied greatly. Starch-based polymers had the fastest rate of hydration (<2 hours), followed by a propenoate-propenamide copolymer. Polyacrylamide materials required 4 to 8 hours to become fully hydrated. Maximum water retention in distilled water varied from 400 to 57 g of water per gram of dry material. All hydrogels retained less water in the presence of metal ions or fertilizers in the soaking solution, with substances releasing Fe$^{+2}$ being the most detrimental. After exposure to fertilizers and ions, the water-holding capacity of a polyacrylamide with a high degree of cross linkage, but not that of hydrogels of the other structures, was fully recovered by subsequently soaking in distilled water. Pots amended with a polyacrylamide polymer but without Micromax (a micronutrient source) reached maximum water retention after six irrigations, while those with Micromax required 10 irrigations to reach peak water retention. The amounts of water being held in pots decreased after repeated fertilization. Medium volume increased with increasing levels of the polyacrylamide Supersorb C (0, 2, 4, or 6 g/pot). Micromax incorporated in medium amended with Supersorb C caused a depression in volume. Medium bulk density, total water retention, and water retention per unit volume of medium were increased by the incorporation of the hydrogel, regardless of the presence of Micromax. Noncapillary porosity measured at container capacity in medium amended with Micromax progressively decreased as the amount of hydrogel increased, but remained unchanged in medium without Micromax. Repeated drying and dehydration of the medium resulted in reduced water retention and increased noncapillary pore space.**

Horticultural application of hydrophilic polymers (hydrogels) has drawn research attention during the recent years (Henderson and Hensley, 1985; Ingram and Yeager, 1987; Tu et al., 1985; Wang, 1989b; Wang and Boogher, 1987). Despite the various degrees of water absorption claimed by manufacturers, the amount of water being retained by hydrogels can be adversely affected by chemicals or ions present in the water (James and Richards, 1986; Johnson, 1984; Wang, 1987). It has not been documented if the adverse effect of ions on hydrogel hydration is reversible. Although experiments have been conducted to study the effect of hydrogels on plant growth, it remains unclear what effect the addition of hydrogels to a potting medium would have on its physical properties. In several studies, changes in the volume of media in the presence of hydrogels were not reported, making it difficult to determine the factor(s) contributing to the altered water-holding capacities of the media (Ingram and Yeager, 1987; James and Richards, 1986; Johnson, 1984).

The objectives of this study were to determine 1) rates of water uptake and the effect of several soil amendments on water retention by several hydrogels, 2) water retention and physical properties of a potting medium in response to incorporation of a hydrogel, a micronutrient fertilizer, and irrigation, and 3) effect of repeated drying-rehydration on medium physical properties.

## Materials and Methods

*Effect of soaking time and soil amendments on water uptake.* Hydrogels used in this study could be separated into three categories: 1) starch-based materials—Liqua-Gel (Miller Chemical and Fertilizer Corp., Hanover, Pa.), Water-Lock B-204 (Grain Processing Corp., Musscatine, Idaho), and Sta-Wet (Polysorb, Smelterville, Idaho); 2) polyacrylamide and related materials–Agrosoke (Agrosoke, Fort Worth, Texas), Aqua-Lox (Soil Tech, Fort Worth, Texas), Broadleaf P-4 (Broadleaf Industries, San Diego), Supersorb C (Aquatrols Corp. of America, Pennsauken, N.J.), and Terra-sorb (Industries Services Intl., Bradenton, Fla.); and 3) propenoate-propenamide copolymers - Viterra (Nepera Chemical Co., Harriman, N.Y.). One gram of each hydrogel was placed in a beaker and then filled with 1 liter of distilled water. Hydrogels were allowed to soak in water at 25 ± lC for 5, 10, 20, 30, 60, 120, 240, or 480 rein, drained for 5 rein, and weights of the hydrated materials recorded. Each material was tested on a separate day. Tukey's honest significance difference (HSD) procedure was used for separating water absorption by various hydrogels for each given soak period and levels of water retention among soaking times.

To determine the effect of soil amendments on water uptake, 1 g of each hydrogel was placed in individual beakers. The beakers were filled with 1 liter of distilled or tap water, or with solutions containing Micromax (1.2 g, a micronutrient source; W.R. Grace and Co., Cambridge, Mass.), ferrous sulfate (2 g, $FeSO_4$-$7H_2O$, analytical grade), Dolomite (7 g, a fine-ground dolomitic limestone), sodium ferric ethylenediamine di-(o-hydroxyphenyl)-acetate (0.2 g, Sequestrene 138; Ciba-Geigy, Greensboro, N.C.), or a 24N-3.5P-13.3K water-soluble fertilizer (0.84 g, W.R. Grace and Co.) in distilled water. The tap water had an electrical conductance (EC) of 1.45 $dS\cdot m^{-1}$ and contained high levels of Ca$^{+2}$, Mg$^{+2}$, and Na$^{+}$ ions (Wang, 1989a). Hydrogels were immersed in solutions for 4 hr, drained for 5 rein, and their weights recorded. Tukey's HSD was used

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[1] Associate Professor.

[2] Technician.

for mean separations among hydrogels for each treatment and for separating the effect of various treatments on each hydrogel.

To determine the recovery of water uptake by three hydrogels after exposure to fertilizers, 1 g of Viterra, Agrosoke, and Supersorb C was each sequentially soaked in 500 ml of tap water (16 hr), distilled water (2 hr), solutions containing a water-soluble 24N-3.5 P-13.3K fertilizer (0.42 g, 2 hr), and ferrous sulfate pentahydrate (1 g, 2 hr), then twice in distilled water (18 and 5 hr). After each soak, excess solution was drained for 5 min and weights of hydrogels were recorded. Tukey's HSD was used for separating treatment effects for each hydrogel. Treatments in all of the above experiments were replicated three times in a randomized complete-block design.

*Effect of hydrogel and micronutrients on water retention and physicalproperties of a medium.* A common basal medium consisting of equal volumes of peatmoss and composted pine bark with fine-ground dolomitic lime at 4 kg·m$^{-3}$ was prepared. Pots (2-liter volume, 16.3 cm top id. and 12.7 cm tall) were filled with 450 g of the medium amended with the polyacrylamide Supersorb C at levels of O, 1, 2, or 3 kg·m$^{-3}$ (equivalent to O, 2, 4, or 6 g/pot, respectively). Half of the pots had Micromax incorporated into the medium at 1 kg·m$^{-3}$. Pots were placed on a greenhouse bench, irrigated twice, each time with 500 ml of water (EC < 0.012 dS·m$^{-1}$, from a reverse osmosis (RO) system, and allowed to drain for 30 min before weights were recorded. For each of the next 13 days, each pot received 500 ml of RO water and was weighed after having drained. Starting on the 15th day, and continuing for an additional 6 days, each pot received 500 ml of RO water daily containing 0.42 g of a 24N–3.5P-13.3K water-soluble fertilizer (W.R. Grace and Co.) and was weighed after having drained. Instead of regression analysis, HSD was used for mean separation within each Micromax treatment due to the sharp drop in water-holding capacities following the application of fertilizer. Regression analysis was used to describe treatment effect following each irrigation.

All pots, at their container capacities, were brought to a laboratory for the determination of medium physical properties using procedures similar to those described by Joiner and Conover (1965). A layer of a thin polyethylene film was placed on top of the medium within the rim of the pot. Water was slowly added to the exposed surface of the polyethylene until the water surface was level with the rim. This water was poured into a beaker, weighed, and subtracted from 2 liters to estimate the volume of the medium in the pot. The pot was then placed in a bucket, and water was slowly added to the bucket until its surface reached the level of the medium in the pot and the medium surface glistened. The pot was quickly lifted from the container, placed in a large pan, and weighed. The pot was subsequently drained for 24 hr in an environment with 100'% RH and weighed again. Bulk density of the fully hydrated medium, noncapillary pore space (by subtracting weight of medium after draining for 24 hr from that of saturated weight and then dividing by medium volume), total water retention, and water content per unit volume of medium were calculated for each pot.

All pots were then brought back to the greenhouse and irrigated with 500 ml of tap water every 2 weeks. After 18 weeks, pots were watered twice, placed in pans filled with water for 24 hr to ensure complete hydration. Physical properties were then determined again as described above. The medium was air-dried, then placed in a forced-air oven at 70C until constant weight was reached, and dry weight was recorded. Each treatment had a single pot as an experimental unit and was replicated four times in a randomized complete-block design. Linear and quadratic regression analyses were used for determining treatment effects.

## Results

Rate of hydration in distilled water varied drastically among hydrogels (Table 1). All starch-based materials absorbed water very quickly. For instance, Water Lock reached 78% of its full capacity in 5 min. The other types of hydrogels required 120 min or more of soaking in water to reach full hydration. Broadleaf P4 had the fastest rate of hydration among the polyacrylamide materials tested, being fully hydrated in 120 min. All other polyacrylamide hydrogels required 480 min in distilled water to reach complete hydration.

The maximum water retention by each hydrogel after soaking in distilled water also varied substantially_ (Tables 1 and 2). Viterra, the propenoate-propenamide copolymer, had the highest water-holding capacity, whereas Agrosoke, a polyacrylamide, had the lowest. All hydrogels retained much less water when hydrated in tap water high in dissolved salts or in water containing chemical amendments, regardless of their levels of water retention in distilled water (Table 2). Ferrous sulfate was particularly damaging to the starch-based hydrogels. Micromax contains ferrous sulfate as the source of iron, and its effect on hydrogel hydration was similar to that of ferrous sulfate alone. Dolomite and Sequestrene 138 had less deleterious effects on hydrogels than other substances used in this experiment. The water-soluble fertilizer depressed the water retention of all hydrogels and it affected some more than the others.

The reduced water-holding capacities of Viterra, Agrosoke, and Supersorb C, as the result of soaking in tap water, were partially recovered after a subsequent soak in distilled water (Table 3). Water was released by all expanded hydrogels following additional soaks in fertilizer and ferrous sulfate solutions. After two extra soaks in distilled water, the water-holding capacity of Agrosoke was completely recovered and that of Supersorb C was partially recovered. However, Viterra had lost its integrity and could hardly be held by the sieve, suggesting that its structure had been disrupted.

Medium amended with Supersorb C had increased water retention relative to the base medium upon the first irrigation (Table 4; for briefness, only selected data are presented.). Pot weights continued to increase with increasing number of irrigations, with significant difference among levels of the hydrogel. Pots without the hydrogel reached their maximum water-holding capacities after six irrigations. Those amended with the hydrogel, but without Micromax, reached maximum retention after eight irrigations, while pots with hydrogel and Micromax continued to absorb water until the 10th irrigation was completed. Pot weights declined' after being irrigated with water containing fertilizer, except those without the hydrogel. More water was released by the medium with increasing levels of Supersorb C. Additional irrigations with fertilizer resulted in a continuous decline of pot weight. At any given level of Supersorb C, pots without Micromax retained more water than those with Micromax (Table 4). However, the effect of Micromax on water retention declined after several irrigations and diminished completely after seven irrigations with fertilizer water.

Physical properties of the base medium following watering and fertilization were altered by the addition of Supersorb C and micronutrients. Medium volume increased with increasing levels of hydrogel (Table 5). Although incorporation of Micromax resulted in less medium volume than that without Micro-

Table 1. Amount of water absorbed by various synthetic hydrophilic polymers. Hydrated polymers were drained for 5 min before weighing.

| Hydrogel | Type$^z$ | 5 | 10 | 20 | 30 | 60 | 120 | 240 | 480 | HSD 0.05 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Soaking time (min) | | | | | | | | |
| | | *Water retention (g water/g dry hydrogel)$^y$* | | | | | | | | |
| Water Lock | S | 320 | 364 | 377 | 392 | 396 | 393 | 400 | 406 | 22 |
| Liqua-Gel | S | 185 | 229 | 235 | 233 | 234 | 240 | 267 | 280 | 30 |
| Aqua-Lox | P | 173 | 176 | 222 | 286 | 279 | 292 | 320 | 314 | 22 |
| Viterra | PPC | 167 | 179 | 290 | 333 | 449 | 501 | 536 | 560 | 45 |
| Broadleaf P4 | P | 135 | 181 | 264 | 322 | 375 | 412 | 427 | 427 | 32 |
| Terra-Sorb | P | 53 | 58 | 136 | 159 | 256 | 325 | 394 | 424 | 11 |
| Supersorb C | P | 31 | 48 | 90 | 105 | 191 | 262 | 322 | 355 | 14 |
| Agrosoke | P | 15 | 22 | 22 | 35 | 41 | 53 | 61 | 73 | 7 |
| HSD 0.05 | | 35 | 38 | 28 | 13 | 16 | 19 | 17 | 31 | |

$^z$S = starch-based material, P = polyacrylamide or related material, and PPC = propenoate-propenamide copolymer.

$^y$Means are averages of three replicates.

Table2. Effect of water source and common potting medium amendments on the water retention of several hydrophilic polymers (hydrogels). Hydrogels were soaked in each solution for 4 hr, drained for 5 rein, and then weighed.

| Hydrogel | Distilled water | Tap water$^z$ | Micromax (1.2g·liter$^{-1}$) | $FeSO_4$ (2.0gliter$^{-1}$) | Dolomite (7g·liter$^{-1}$) | Sequestrene 138 (0.2g·liter$^{-1}$) | Fertilizer (0.84 g·liter$^{-1}$)$^y$ | HSD 0.05 |
|---|---|---|---|---|---|---|---|---|
| | | | | *Water retention (g water/g dry hydrogel)$^x$* | | | | |
| Water Lock | 401 | 56 | 34 | 18 | 208 | 261 | 118 | 12 |
| Aqua-Lox | 291 | 70 | 50 | 49 | 190 | 213 | 113 | 12 |
| Liqua-Gel | 232 | 27 | 2 | 4 | 165 | 180 | 122 | 37 |
| Sta-Wet | 133 | 28 | 8 | 7 | 115 | 109 | 75 | 7 |
| Viterra | 544 | 79 | 52 | 47 | 339 | 322 | 163 | 16 |
| Broadleaf P4 | 435 | 89 | 74 | 64 | 299 | 280 | 144 | 16 |
| Terra-Sorb | 395 | 83 | 76 | 69 | 283 | 257 | 69 | 7 |
| Supersorb C | 332 | 88 | 70 | 70 | 252 | 232 | 135 | 12 |
| Agrosoke | 57 | 20 | 23 | 19 | 33 | 38 | 25 | 3 |
| HSD 0.05 | 35 | 10 | 7 | 6 | 19 | 11 | 7 | |

$^z$Water had an electrical conductance of 1.45 dS·m$^{-1}$.

$^y$From a 24N–3.5P-13.3K water-soluble fertilizer (W. R. Grace and Co.).

$^x$Means are averages of three replicates.

Table3. Effect of sequential exposures to tap water, distilled water, soluble fertilizer, $FeSO_4$, and distilled water on water-holding capacities of three hydrophilic polymers. Hydrated polymers were drained for 5 min after each treatment before soaking in the successive solutions. Five hundred milliliters of solution was used for each treatment.

| Sequential exposure | Length of time (hr) | Water retention$_z$ (g water/g dry polymer) | | |
|---|---|---|---|---|
| | | Viterra | Agrosoke | Supersorb C |
| Tap water | 16 | 83 | 19 | 67 |
| Distilled water | 2 | 184 | 26 | 122 |
| 200 mg N/liter$^y$ | 2 | 141 | 22 | 98 |
| $FeSO_4$ | 2 | 59 | 22 | 46 |
| Distilled water | 18 | 9 | 27 | 52 |
| Distilled water | 5 | 6 | 65 | 73 |
| HSD 0.05 | | 8 | 4 | 6 |

$^z$Means are averages of three replicates.

$^y$From a 24N-3.5P-13.3K water-soluble fertilizer at 0.84 g-liter-l (W.R. Grace and Co.).

max, the percentages of reduction were small (<5%). The weight of fully hydrated medium, bulk density, total water retention, and water retention by a unit volume of medium were increased by the hydrogel whether or not Micromax was present. Noncapillary porosity at container capacity progressively decreased as the amount of hydrogel increased in medium amended with Micromax, but remained unchanged in medium without the micronutrients (Table 5). Total water retention on a per-pot basis was unaffected by Micromax.

After repeated drying and dehydration, the medium volume and weight, as well as water-holding capacities, were greater with increasing amounts of Supersorb C (Table 6). Bulk density of medium without Micromax was not affected by Supersorb C, while that of medium amended with Micromax increased as hydrogel level increased. Changes in noncapillary porosity followed the same patterns described previously. Micromax had no significant effect on the amount of water retained in pots. Although no statistical comparisons were made, it was obvious that repeated drying caused the medium volume, water-holding capacities, and bulk density to decline, even after complete hydration (Tables 5 and 6). However, noncapillary porosity increased.

## Discussion

Starch-based hydrogels have many polar hydroxyl groups that may make it easier for the polar water molecules to be adsorbed to the hydrogels, resulting in fast water uptake and expansion of the materials. Both Liqua-Gel and Viterra (containing 7.8% K) have many – COO$^-$K$^+$ groups that may behave as salts, and thus increase their affinity to water. Plants grown in medium with a hydrogel containing – COO$^-$K+ had increased K levels in their tissues (Taylor and Halfacre, 1986), suggesting the pos-

Table 4. Water absorption by a potting medium as affected by the addition of Supersorb C and Micromax. Each pot contained 450 g of medium at the beginning.

| Level of Supersorb C (g/pot) | Weight (g/pot)[z] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. irrigations (500 ml/each)[y] | | | | | | | | | | | |
| | Reverse osmosis water | | | | | | | | Fertilizer water | | | |
| | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 14 | 15[x] | 18 | 21 | HSD 0.05 |
| | *Micromax (MX, 1 kg·m$^{-3}$)* | | | | | | | | | | | |
| 0 | 939 | 1012 | 1043 | 1059 | 1084 | 1088 | 1107 | 1118 | 1116 | 1134 | 1084 | 24 |
| 2 | 976 | 1090 | 1137 | 1163 | 1204 | 1232 | 1254 | 1264 | 1241 | 1207 | 1161 | 18 |
| 4 | 1004 | 1163 | 1243 | 1294 | 1374 | 1445 | 1484 | 1493 | 1448 | 1318 | 1269 | 21 |
| 6 | 1031 | 1234 | 1332 | 1401 | 1516 | 1620 | 1692 | 1728 | 1630 | 1428 | 1361 | 16 |
| Significance | | | | | | | | | | | | |
| Linear | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | | |
| Quadratic | NS | NS | NS | NS | NS | NS | ** | ** | ** | ** | * | |
| | *No Micromax (no MX)* | | | | | | | | | | | |
| 0 | 953 | 1036 | 1064 | 1080 | 1102 | 1107 | 1125 | 1127 | 1126 | 1142 | 1098 | 13 |
| 2 | 996 | 1168 | 1244 | 1280 | 1315 | 1325 | 1337 | 1332 | 1297 | 1236 | 1181 | 14 |
| 4 | 1021 | 1276 | 1400 | 1466 | 1531 | 1551 | 1570 | 1568 | 1482 | 1321 | 1257 | 29 |
| 6 | 1071 | 1372 | 1548 | 1644 | 1744 | 1794 | 1811 | 1811 | 1670 | 1429 | 1351 | 27 |
| Significance | | | | | | | | | | | | |
| Linear | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | |
| Quadratic | NS | ** | ** | ** | NS | NS | NS | * | NS | NS | NS | |
| Main effect | | | | | | | | | | | | |
| MX vs. no MX | ** | ** | ** | ** | ** | ** | ** | ** | ** | * | NS | |

[z] Means are averages of four replicates.

[y] Pots received two 500 ml of water at the first irrigation.

[x] Pots received 500ml water with 24N-3.5P-13.3K water-soluble fertilizer (O.84g·liter$^{-1}$) each day.

NS*, ** Nonsignificant or significant at $P = 0.05$ and 0.01, respectively.

Table 5. Effect of Supersorb C and Micromax on medium physical properties following repeated watering and fertilization.[z]

| Level of Supersorb C (g/pot) | Medium volume (cm$^3$) | Medium (g/pot) | Bulk density (g·cm$^{-3}$) | Noncapillary porosity (%) | Total water (g/pot) | Water retention (g $H_2O$/ cm$^3$medium) |
|---|---|---|---|---|---|---|
| | | | *Micromax (MK, 1 kg·m$^{-3}$)* | | | |
| 0 | 1697 | 1091 | 0.642 | 30.8 | 851 | 0.501 |
| 2 | 1720 | 1153 | 0.670 | 29.5 | 913 | 0.531 |
| 4 | 1826 | 1249 | 0.684 | 29.2 | 1007 | 0.551 |
| 6 | 1899 | 1328 | 0.699 | 27.0 | 1083 | 0.570 |
| Significance | | | | | | |
| Linear | ** | ** | ** | ** | ** | ** |
| Quadratic | NS | NS | NS | NS | NS | NS |
| | | | NoMicromax(noMX) | | | |
| o | 1650 | 1084 | 0.657 | 29.5 | 846 | 0.513 |
| 2 | 1813 | 1171 | 0.646 | 31.8 | 936 | 0.516 |
| 4 | 1899 | 1257 | 0.662 | 31.8 | 1019 | 0.537 |
| 6 | 1955 | 1311 | 0.671 | 31.6 | 1074 | 0.549 |
| Significance | | | | | | |
| Linear | ** | ** | * | NS | ** | ** |
| Quadratic | ** | * | ** | NS | * | * |
| Main effect | | | | | | |
| MX vs. noMX | * | NS | ** | ** | NS | * |

[z] Means are averages of four replicates.

NS,*,**Nonsignificant or significant at $P = 0.05$ and 0.01, respectively.

sibility of dissociation of K from the hydrogel. It is not clear whether the increased tissue K level was solely the result of increased K concentration due to the hydrogel in the amended medium.

The degree of cross-binding (provided by acrylic acid) to hold the long chains of acrylamide together determines the behavior of a polyacrylamide. A high degree of cross-linkage (such as in Agrosoke) results in the material having a relatively low water-retention capacity (Table 2), yet it renders a higher degree of resistance to the damage caused by various salts (Table 3). Because of the large amount of cross-linkage, the reduced water retention of Agrosoke, as the result of exposure to various ions,

Table 6. Effect of Supersorb C and Micromax on medium physical properties after repeated drying and wetting (pots received 500 ml of water every 2 weeks) for 18 weeks.’

| Level of Supersorb C (g/pot) | Medium volume ($cm^3$) | Medium wt (g/pot) | Bulk density ($g \cdot cm^{-3}$) | Noncapillary porosity (%) | Total water (g/pot) | Water retention ($g H_2O/$ $cm^3$ medium) |
|---|---|---|---|---|---|---|
| *Micromax (MX, 1 $kg \cdot m^{-3}$)* | | | | | | |
| 0 | 1560 | 983 | 0.630 | 36.7 | 743 | 0.476 |
| 2 | 1611 | 1028 | 0.638 | 36.4 | 788 | 0.489 |
| 4 | 1724 | 1095 | 0.635 | 34.7 | 853 | 0.495 |
| 6 | 1731 | 1146 | 0.662 | 34.6 | 901 | 0.521 |
| Significance | | | | | | |
| Linear | ** | ** | ** | * | ** | ** |
| Quadratic | NS | NS | NS | NS | NS | NS |
| *No Micromax (no MX)* | | | | | | |
| 0 | 1559 | 964 | 0.618 | 36.8 | 726 | 0.466 |
| 2 | 1655 | 1021 | 0.617 | 38.1 | 786 | 0.475 |
| 4 | 1740 | 1091 | 0.627 | 37.2 | 853 | 0.490 |
| 6 | 799 | 1135 | 0.631 | 38.7 | 898 | 0.499 |
| Significance | | | | | | |
| Linear | ** | ** | NS | NS | ** | ** |
| Quadratic | NS | NS | NS | NS | NS | NS |
| Main effect | | | | | | |
| MX vs. no MX | * | NS | ** | * | NS | ** |

[z] Means are averages of four replicates.

NS,*,* * Nonsignificant or significant at $P = 0.0.5$ and 0.01, respectively.

was fully recovered after subsequent soaks in distilled water. Viterra had an outstanding. water absorption in distilled water; however, it was physically unstable in the presence of salts due to less or weak cross-linkage. Therefore, the degree of cross-linkage holding the long chain molecules together needs to be balanced carefully to give adequate water retention while keeping the material’s structure reasonably rigid.

Although starch-based materials absorbed water very quickly, their abilities to retain water in solutions containing ferrous and other ions were impaired to a much higher degree than polyacrylamides. Cations, such as $Na^+$, $Ca^{+2}$, and $Mg^{+2}$, have been shown to reduce water absorption by hydrogels, with the divalent ions being particularly damaging to the structure of all types of hydrogels (Johnson, 1984; Evans and Bowman, 1989). Dolomite, containing Ca and Mg, has limited volubility in water; therefore, it had less effect on hydrogel water retention than substances containing water-soluble Ca (Johnson, 1984). James and Richards (1986) have suggested that multivalent cations actively dislodged and replaced water molecules at polarized sites upon and within polymers. Evans and Bowman (1989) showed that the reduced water absorption brought about by monovalent ions was fully reversible by repeated soaking with deionized water, whereas the damaging effect of divalent ions on hydrogel water retention was irreversible. In our study, ferrous sulfate and Micromax appeared to have completely destroyed the integrity of several hydrogels other than those made of polyacrylamide.

The water absorption pattern (Table 4) showed that a medium did not reach its maximum hydration until after several irrigations, and repeated drying-rehydration cycles drastically reduced the water-holding capacity of a medium (Tables 5 and 6). This was more obvious when a hydrogel had been incorporated into the medium. Although 8 hr was long enough for all hydrogels to reach full hydration in distilled water, they took a much longer time to reach full expansion in a potting medium. The above suggests that hydrogels may require the presence of free water for quick expansion and are unable to extract water effectively from an unsaturated medium. We have noticed the fast expansion of the volume when a potting medium amended with a hydrogel was placed in a propagation bed with intermittent mist or had received prolonged rain. Under nursery conditions, pots with living plants are amended with many fertilizers and watered only when the medium has lost much of its available water. Therefore, a hydrogel’s capacity to retain water in practice would be far below its maximum capacity. It may be beneficial to irrigate the pots containing a hydrogel before the medium becomes too dry.

Although Micromax resulted in slower initial water uptake, it had little effect on the total amount of water being held by a medium after repeated watering and fertilization. However, addition of Micromax to a potting medium amended with a hydrogel resulted in the reduction of medium volume, possibly due to the weakening of the gel structure. As a result of compaction, as shown by the lower noncapillary porosity of medium amended with the hydrogel, Micromax actually increased the water-holding capacity of the medium when measured on the basis of a unit volume of the medium. The porosity at any level of Supersorb C, regardless of Micromax, was adequate for good plant growth (Conover and Poole, 1981, 1988; Poole et al., 1981).

Hydrogel manufacturers often recommend placing less medium in pots when a hydrogel is used, so that the medium does not expand over the rims. Although in some cases, such as in areas where high-quality water is available, this practice may be necessary; in most production areas it may interfere with obtaining the full benefits of using a hydrogel. For example, pots amended with Micromax and Supersorb C at rates of 2, 4, or 6 g had 62, 156, and 232 g of extra water, respectively, after 21 irrigations (subtracting total water in the control from that of each treatment) (Table 5). On the contrary, they would have held only 50, 72, and 116 g of extra water (multiplying the water retention per cubic centimeter of medium by the volume of the control and subtracting the amount of water held by the control), respectively, if the amount of medium had been proportionally reduced at the beginning so that the final volumes were equivalent to that of the control. Similarly, the increased water content in medium with SuperSorb C, but without Micromax, was mainly due to the increased volume as the result of hydrogel incorporation. Thus, a large reduction in the amount of medium per pot, while using a hydrogel, should be avoided.

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