EFFECT OF HYDROPHILIC GELS ON SEED GERMINATION AND PLANT ESTABLISHMENT

by

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LITERATURE REVIEW

INTRODUCTION

Available water is that portion of stored soil moisture that can be absorbed by plant roots rapidly enough to sustain life. Lack of adequate water (drought stress) reduces the growth and quality of plants as well as crop yield. Plants are susceptable to moisture stress at all stages of growth. Any practice which decreases moisture stress should be, therefore advantageous.

Hydrophilic gels are compounds which absorb many times their weight in water, then release this moisture to the surrounding environment as it becomes dry (Alston, 1982). The use of hydrophilic gels to retain moisture around germinating seeds and roots of new transplants could provide an immediate source of moisture, thereby improving plant growth and yield.

EFFECTS OF DROUGHT STRESS ON SEEDS AND PLANT PROCESSES

Kramer (1983), Hsiao (1973) and others have discussed the effect of low moisture levels on various plant processes in detail. The amount of water necessary to avoid drought stress during seed germination appears to vary with the type of seed, with each seed having a minimum moisture content necessary for germination (Hunter and Erickson, 1952). This minimum moisture content can only be determined by testing individual seed types. McGinnies (1960), however, found a positive correlation between seed size and germination at 1.5 MPa of moisture.

Several other correlations have also been noted between moisture stress, seed germination and seedling growth. Most indicate that acceptable seed germination occurs throughout the range of available water (0 to -1.5 MPa) (Donahue, Miller and Shickluna). As available moisture decreases, however, germination rate decreases and the time to emergence increases (Doneen and McGillivray, 1943; Ayers, 1952; McGinnies, 1960; Therios, 1982).

Plant response to moisture stress after germination appears to be independent of its germination response (McGinnies, 1960). A species which germinates well under severe drought stress will not necessarily withstand drought at maturity, and one which germinates poorly under drought stress may well withstand drought as a mature plant.

Once germination is complete, water continues to be a limiting factor for plant growth and activity (Langhans and Spomer, 1972). Moisture affects most plant processes and moisture deficits influence plant growth and yield. The extent of influence depends upon the intensity and duration of moisture deficit as well as plant species (Bradford and Hsiao, 1982). Sensitive processes are altered by mild stress and as stress increases, alterations intensify and other processes become affected.

One of the more noticeable water stress affects is a reduction in plant growth. Cell division and cell enlargement are required for growth, and both processes are reduced by moisture deficits (Kramer, 1983). In many species, cell expansion is one of the processes which is most sensitive to moisture stress (Hsiao, 1973). This reduction in cell expansion has been attributed to a reduction in cell turgor. The effect of moisture stress on cell division is not as well understood. The effect is thought to be more indirect, possibly due to decreased cell expansion, since mitosis (and therefore cell division) depends upon cell enlargement after division to some extent (Doley and Leighton, 1968).

Several methods may be utilized for assessing the moisture status of plants, but water potential is probably the most useful (Kramer, 1983). Water potential is a measure of the free energy of water in plant tissue, soil and solutions and can be related to atmospheric moisture. Plant water potential is commonly measured with thermocouple psychrometers (Monteith and Owen, 1958) or a pressure chamber (Scholander, et al., 1965).

Stomates are also sensitive to reduced moisture levels. Drying soil drastically reduces transpiration because of decreased water absorption, producing a leaf water deficit which causes stomatal closure (Kramer, 1983; Hsiao, 1973). The development of the stomatal diffusion porometer (Kanemasu, Thurtell and Tanner, 1969) has allowed researchers to measure stomatal conductance.

HYDROPHILIC GELS AND SEED GERMINATION

Hydrophilic gels are compounds which, according to manufacturers, improve seed germination and seedling survival. The compounds absorb many times their weight in moisture, then release it to the environment as it becomes dry. Theoretically, seeds coated with hydrophilic gels should be exposed to improved germination conditions since moisture should be more readily available.

Seeds can be exposed to hydrophilic gels by several techniques. Seed can be 1) coated with the hydrophilic material; 2) planted in a medium amended with the material; or 3) placed in hydrophilic gel used as a medium for fluid drilling.

Results of studies examining the effects of seed coatings on germination and seedling growth conflict. Rodgers and Anderson (1981) determined that seeds coated with Super Slurper[1] and grown in strip mine spoil had a higher initial germination rate than did untreated seeds. Another study, however, found seeds coated with Viterra 2 Hydrogel[2] or Super Slurper to germinate at a rate equal to, or lower than, uncoated seeds (Berdahl and Barker, 1980).

Varying results have also come from studies in which hydrophilic gels were used as media-amendments during seed germination. Corn (<u>Zea mays</u> L.) placed in sandy soil amended

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[1] Super Slurper is a starch-based absorbent developed by the USDA Northern Regional Research Center, Peoria, IL.

[2] Viterra 2 Hydrogel is the registered trademark for a copolymer of acrylamide and potassium acrylate manufactured by Nepera Chemical Co., Inc., Harriman, NY under license from Union Carbide Corp.

with hydrophilic gel germinated and grew more rapidly than in unamended soil (El-Hady, Tayel and Lofty, 1981). Germination of Phaseolus vulgaris L. 'Topcrop' in 10 cm growing containers with Metro Mix 300 improved when amended with Terra-sorb[3], but no difference was apparent in 15 cm containers (Munday, 1981).

Rietveld (1976) found a delay and reduction in germination of ponderosa pine (Pinus ponderosa Dougl. ex P. Laws & C. Laws) seed when seeded areas were amended with hydrophilic gel. Survival and growth after emergence was not affected, however. Rietveld (1976) theorized that large amounts of hydrophilic gel may retain excessive amounts of moisture, decreasing aeration. Similarly, Berdahl and Barker (1980) found that with higher concentrations of hydrophilic materials as a seed coating, water holding capacity increased, but aeration was apparently reduced. This hypothesis was substantiated by other studies in which pepper (Capsicum annuum L.) seeds were coated with clay or sand (Sachs, Cantliffe and Nell, 1981, 1982). Germination was decreased in coated seeds; however, when the coated seeds were placed in a high oxygen environment, germination was comparable to untreated seeds germinated in air. Reduced seedling vigor of pregerminated snapdragon (Antirrhinum majus L.) seeds stored in hydrophilic gels correlated with decreased oxygen diffusion rates through the material (Frazier, Wiest and Wootton, 1982).

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[3] Terra-sorb is the registered trademark of a gelatinized starch-hydrolyzed polyacrylonitrile graft copolymer using potassium hydroxide distributed by Industrial Services International, Inc., Bradenton, FL.

Other factors may also contribute to reduced germination rates in the presence of hydrophilic gels. In one study, Super Slurper began to absorb water and seeds began to grow, but the soil was too hard for roots to penetrate, resulting in seedling death (Searle, 1977). In this situation, it may have been advantageous for the seed to remain dormant until adequate moisture was available for plant growth and root penetration.

Hydrophilic gels have also been used as a medium for fluid drilling pregerminated seeds with some success. Plant stand of celery (*Apium graveolens* L.) seeds sown in a gel was 60% compared to a stand of 2% from dry seeds (Currah, Gray and Thomas, 1974). Plant growth of carrot (*Daucus carota* L.) was also enhanced by fluid drilling (Finch-Savage and Cox, 1982). Fluid drilled plants reached an economical yield of marketable-sized roots before those reached from dry seed.

EFFECT OF HYDROPHILIC GELS ON PLANT ESTABLISHMENT AND GROWTH

The use of hydrophilic gels in transplanting is purported by manufacturers to help decrease recovery time and increase survival. These benefits reportedly are due to improved root development of plants exposed to hydrophilic gel treatments[4].

Two techniques are commonly used to expose plants to hydrophilic gels at transplanting: 1) dipping the root system into a solution of hydrophilic gel; and 2) amending backfill medium with the hydrophilic material.

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[4] "Terra-sorb in Transplanting." Product Bulletin #2. Industrial Services International, Inc., Bradenton, FL.

As was apparent in seed germination studies, results have varied from studies examining the efficacy of hydrophilic gels in transplant establishment and survival. Pepper transplants dipped in a hydrophilic gel prior to shipping from Georgia to New Jersey were shorter but more branched than untreated plants once they were established (Johnson, 1982). Yield of the dipped plants was slightly higher than that of controls, possibly due to the increased branching.

Hydrophilic gel improved survival of Blackhill Spruce (Picea glauca Moench.) in Wisconsin (Whitmore, 1982). Trees were planted with and without a root dip in a hydrophilic compound, and no additional moisture was applied for three weeks. Survival of treated plants was 80%; whereas, 50% of untreated plants survived. Treated trees also had better root systems than untreated later in the season.

Goodwin (1982) tested the effects of various materials used as root dips for Loblolly Pine (Pinus taedia L.) and found no significant difference in survival or height between trees dipped in water and those dipped in a Terra-sorb solution. Similar results were apparent for winter jasmine (Jasminium nudiflorum Lindl.) and purple-leaf wintercreeper (Euonymous fortunei Turcz. 'Colorata') in that growth and survival of plants dipped in Terra-sorb did not statistically differ from untreated plants (Hensley and Fackler, 1984).

The use of hydrophilic gels as media amendments has been shown to affect soil characteristics and plant establishment.

Hemyari and Nofziger (1981) suggested that amendment with Super Slurper increased the moisture holding capacity of coarser-textured soils (sandy loam and loamy sand) but had little effect in a clay loam, except with high rates.

Several studies have examined plant growth in gel-amended media. Dry weights of 'Sunny Mandalay' chrysanthemums (Chrysanthemum morifolium Ramat. 'Sunny Mandalay') grown in hardwood bark mix amended with Viterra 2 Hydrogel did not significantly differ from the dry weights of control plants at normal amendment rates. When high rates of hydrophilic material were utilized, dry weights were reduced (Still, 1976). This reduction in growth was attributed to reduced aeration. Similar results were apparent with heights of poinsettias (Euphorbia pulcherima Willd. ex Klotsch) grown in soilless media amended with SGP Water Absorbent Polymer[5] (Criley, 1979).

In contrast, a similar study with 'Bright Golden Anne' chrysanthemums found significant increases in growth of plants grown in Viterra amended peat-lite and bark medias. Significant increases in plant dry weights were also apparent in Easter lilies (Lilium longiflorum Thunb.) and tomatoes (Lycopersicon esculentum L.) (Bearce and McCollum, 1977). Addition of Viterra to the medium on which foliage plants were grown also improved the growth and quality of those plants (Conover and Poole, 1976). The improved plant growth in both

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[5] SGP Absorbent Polymer is the registered trademark of a hydrophilic compound manufactured by Henkel Corp., Minneapolis, MN.

of these studies was attributed to increased aeration and improved soil moisture levels.

Addition of a hydrophilic gel to various container media corresponded with a significant growth increase in golden privet (Ligustrum x vicaryi); however, no differences were apparent in euonymous (Euonymous kiautschovicus Loes.) or crape myrtle (Lagerstroemia indica L.) (Greenwood, Coorts and Maleike, 1978).

The addition of hydrophilic gels to the growing medium consistently increased the shelf life of ageratum (Ageratum houstonianum Mill.), marigold (Tagetes erecta L.) and zinnia (Zinnia elegans Jacq.) (Gehring and Lewis, 1979). A reduction in drought stress of marigold and zinnia resulted from incorporating the Viterra into the growing medium (Gehring and Lewis, 1980).

Serious research on the benefits of hydrophilic gel materials in seed germination and transplanting is limited and the results conflicting. These materials may well prove to be an aid to plant establishment especially in low maintenance or stressful sites. The purpose of these studies was to examine the efficacy of these materials as seed treatments and transplant aids.

CHAPTER II

EFFECT OF HYDROPHILIC GELS ON SEED GERMINATION

INTRODUCTION

According to manufacturers, hydrophilic gels utilized as seed coatings may improve germination rate and plant stand (Deterling, 1981). Results of research in this area conflict (Berdahl and Barker, 1980; Rietveld, 1976: Rodgers and Anderson, 1981). The purpose of this study was to evaluate the effect of hydrophilic gels, utilized as seed coatings on germination and subsequent seedling vigor.

MATERIALS AND METHODS

Greenhouse Studies

Seeds of bean (Phaseolus vulgaris L. 'Avalanche'), pea (Pisum sativum L. 'Mighty Midget'), tomato (Lycopersicon esculentum L. 'Marglobe Large Red'), and okra (Hibiscus esculentus L. 'Clemson Spineless') were coated with Water Lock B100 Absorbent Starch[1] and Terra-sorb using a technique adapted from methods described by the manufacturers. Seeds were weighed and dipped in a 20% (v:v) solution of Co-op Spreader-Activator (octylphenoxypolyethoxyethanol). The moistened seeds were then placed in premeasured mixtures of dry gel:talc (1:1 wt/wt). The seeds and coating material were thoroughly mixed to assure a uniform covering.

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[1] Water Lock B100 Absorbent Starch is the registered trademark of a starch-graft copolymer of potassium polyacrylate and polyacrylamide manufactured by Grain Processing Corp., Muscatine, IA.

Seed coating rates of hydrophilic gel were 1 or 2% by seed weight (1 and 2 times manufacturer recommended rates). Two sets of controls were utilized for these and other seed coating studies. One contained seeds which were not subjected to either adhesive or hydrophilic gel treatments. The other consisted of seeds treated with the adhesive material alone.

Treated seeds of beans, peas, and tomatoes were planted in 15 cm plastic pots of washed river sand and Jiffy Mix, while okra was planted in sand only. Jiffy Mix was chosen as a medium to supply high moisture conditions, while sand provided reduced moisture holding capacity. Each treatment contained 20 seeds and was replicated three times. Seeds were watered approximately every three days and fertilized with 20-20-20 soluble fertilizer periodically.

A separate study utilized the following pine and deciduous hardwood species: Loblolly pine (*Pinus taedia* L.), pitch pine (*Pinus rigida* Mill.), slash pine (*Pinus elliotti* Engelm.), shortleaf pine (*Pinus echinata* Mill.), longleaf pine (*Pinus palustris* Mill.), common honeylocust (*Gleditsia triacanthos* L.), black locust (*Robinia pseudoacacia* L.) and Kentucky coffeetree (*Gymnocladus dioica* L.). All pregermination requirements for the various seeds were satisfied (Schopmeyer, 1974) prior to seed coating treatments.

Seeds were treated with Water Lock B100 Absorbent Starch at two rates, 1% by seed weight, and the maximum amount that seeds would retain when placed in excessive amounts of the product-talc mixture. The procedure for seed coating was as previously described with the exception that Maltrin M100[2] was used as the adhesive material.

Following coating, seeds were planted in sand in 10 cm plastic pots and irrigated at 3, 6, or 9 day intervals. Each treatment contained 15 seeds and was replicated three times.

Seedling emergence in both studies was evaluated and recorded daily. Germination was considered complete when no further seedling emergence was apparent for seven days. Seedling heights of vegetables and deciduous hardwoods were measured 28 days after planting, and pines were measured 42 days after planting. Shoot dry weights were determined after oven drying at 80°C for 48 hours. An analysis of variance and mean separations were performed on all data.

Nonlinear regression analysis fit to the equation:

$$Y = m \log X + b$$

was utilized to predict the number of days to 10% and 50% emergence from recorded emergence data. Analysis of variance and mean separation procedures were conducted to evaluate differences among hydrophilic gel treatments within each species and media-type or irrigation interval.

Field Studies

Seeds of the same pine and deciduous hardwood species utilized in greenhouse studies were treated as previously described and planted on May 23, 1983 in a prepared field of

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[2] Maltrin M100 is a registered trademark of a maltodextrin product manufactured by Grain Processing Corp., Muscatine, IA.

Haynie very fine sandy loam soil at the Ashland Horticultural Farm. Each treatment contained 10 seeds, and was replicated four times. The plots received no fertilizer or supplemental irrigation prior to or during the study. Weather data are listed in Appendix 1. Weeds were removed by hand as necessary.

Seedling emergence was evaluated daily until apparently complete. Above-ground portions of plants were harvested 42 days after planting, and dry weights were determined after drying for 48 hours at 80° C. Statistical analyses were the same as those described for greenhouse studies.

RESULTS AND DISCUSSION

Greenhouse Studies

No significant differences were found within vegetable species or media-type in the number of days to 10% and 50% emergence regardless of seed treatment, as calculated by non-linear regression analysis ($Y = m \log X + b$) (Table II-1). Some trends were apparent; however, these were inconsistent among the species. The most rapid emergence occurred most frequently in seeds treated with 2% Terra-sorb. This was true at the 10% emergence level of beans and peas grown in sand as well as at the 10% and 50% level of tomatoes germinated in both media, and peas germinated in Jiffy Mix. No treatment consistently resulted in the slowest emergence in sand; however, seeds treated with 2% Water Lock and planted in Jiffy Mix frequently emerged more slowly than those exposed to other treatments.

Table II-1. Average time to 10 and 50 percent emergence of four vegetable species in which seeds were treated with two concentrations of two hydrophilic gels and grown in sand and Jiffy Mix. There were no statistical differences between gel treatments for any of the species (F-test).

	Sand								Jiffy Mix					
	Bean		Pea		Tomato		Okra		Bean		Pea		Tomato	
Treatment	10%	50%	10%	50%	10%	50%	10%	50%	10%	50%	10%	50%	10%	50%
Control	10.4	15.0	6.6	8.8	8.7	15.6	3.1	8.6	9.2	13.8	5.2	7.2	12.5	17.5
Sticker	11.6	16.0	6.0	8.9	12.6	22.8	4.7	8.5	10.4	15.3	4.6	6.7	12.8	18.3
1% Terra-sorb	12.2	23.4	5.2	8.0	15.1	32.2	1.9	6.2	8.5	13.9	5.2	6.7	10.9	16.4
2% Terra-sorb	10.1	32.7	4.4	7.5	4.1	9.0	4.5	6.8	9.5	15.2	3.0	5.7	7.9	15.4
1% Water Lock	10.9	19.0	5.0	7.3	7.1	16.2	3.6	9.0	10.0	15.1	4.5	6.7	10.1	17.3
2% Water Lock	13.8	53.4	6.5	8.6	4.1	13.6	3.6	10.1	9.2	16.0	5.4	8.0	12.3	19.1

A potential reduction in aeration may explain some of the trends in this study. Since Water Lock is a very fine-textured coating material, it tended to form a denser covering on the seed than Terra-sorb, a coarse-textured product of similar chemistry. When Water Lock-coated seeds were then placed in Jiffy Mix, the higher moisture of the media and seed coat properties may have combined to reduce aeration, and thus germination. The lower moisture-holding capacity of sand may have increased oxygen content around the seeds, since no treatment showed a consistent alteration in emergence rates. Studies in which pepper seeds were coated with clay or sand (Sachs, Cantliffe and Nell, 1981, 1982) indicated that germination of coated seeds was decreased, apparently due to interference with oxygen diffusion through the coating materials into the embryo.

Berdahl and Barker (1980) found that high concentrations of hydrophilic gels in seed coatings allowed better moisture uptake, but apparently poor aeration reduced germination of Russian wildrye (_Elymus junceus_ Fisch.). Oxygen diffusion rates varied among several hydrophilic gels used as storage mediums for pregerminated snapdragon (_Antirrhinum majus_ L.) seeds (Frazier, Wiest and Wootton, 1982). Seedling viability was lowest in those hydrophilic gels which had the lowest oxygen diffusion rates.

Other differences should be noted in the effects of the two media on seedling emergence. The seeds of beans and peas emerged from Jiffy Mix more rapidly than from sand regardless of seed coating treatments. This difference in emergence rate could again be attributed to differences in moisture holding capacity. Less moisture fluctuation may have occurred in Jiffy Mix than in sand. In contrast to beans and peas, tomatoes were inconsistent in their response to media type.

Coating seeds with hydrophilic gels also had no effect on seedling growth (Table II-2). No significant differences were found in either heights or weights among treatments within species or media-type. There were, however, observable differences in seedling growth between the two growing media. Seedlings grown in Jiffy Mix were consistently taller than the same species in sand, although there were no differences in plant weights. This height differential was possibly due to more consistent water holding capacity or to the increased nutrient content of Jiffy Mix.

No significant differences among treatments occurred in the number of days to 10% and 50% emergence of various pine species (Table II-3) as calculated by nonlinear regression analysis ($Y = m \log X + b$), or in the seedling heights or dry weights (Table II-4). No trends due to treatments were evident among these species. Apparently, hydrophilic gels had little, if any effect on germination, seedling emergence, or growth.

Apparently, pine seeds which were exposed to a stratification period were more sensitive to lower moisture levels, since no emergence occurred at the 6 or 9 day irrigation

Table II-2. Heights and dry weights of four vegetable species grown in sand and Jiffy Mix from seeds coated with hydrophilic gels. There were no statistical differences between gel treatments for any of the species (F-test).

	Sand							Jiffy Mix				
	Bean	Pea		Tomato		Okra		Bean	Pea		Tomato	
Treatment	Wt.[z] (g)	Ht. (cm)	Wt. (g)	Ht. (cm)	Wt. (g)	Ht. (cm)	Wt. (g)	Wt. (g)	Ht. (cm)	Wt. (g)	Ht. (cm)	Wt. (g)
Control	0.21	6.5	0.05	4.3	0.04	5.8	0.05	0.22	7.2	0.05	6.1	0.02
Sticker	0.17	6.6	0.04	4.3	0.03	5.9	0.04	0.19	7.6	0.05	6.5	0.03
1% Terra-sorb	0.21	6.7	0.04	2.8	0.02	6.6	0.05	0.17	7.9	0.05	7.4	0.04
2% Terra-sorb	0.25	6.1	0.04	5.1	0.03	6.6	0.05	0.14	8.3	0.05	6.7	0.03
1% Water Lock	0.20	8.0	0.05	5.5	0.04	6.1	0.04	0.19	8.8	0.05	6.4	0.03
2% Water Lock	0.19	5.6	0.04	4.3	0.03	6.1	0.04	0.20	7.9	0.05	5.9	0.03

[z] Heights and dry weights measured 28 days after planting.

Table II-3. Average time to 10 and 50 percent emergence of four pine species. Seeds were treated with a hydrophilic gel and watered at 3 day intervals. There were no statistical differences among gel treatments within the species (F-test).

	Slash		Loblolly		Shortleaf		Pitch	
Treatment	10%	50%	10%	50%	10%	50%	10%	50%
Control	10.7	21.8	13.6	20.1	14.2	31.1	11.3	28.8
Sticker	12.8	29.0	12.9	20.7	18.0	39.2	10.8	16.6
1% Water Lock	10.9	36.1	14.4	21.2	13.6	34.8	7.1	16.5
Excess Water Lock	15.9	25.8	17.3	25.2	12.9	53.6	10.2	18.7

Table II-4. Average heights and dry weights of four pine species in which seeds were coated with a hydrophilic gel and irrigated at 3 day intervals. There were no statistical differences between treatments for any of the species (F-test).

Treatment	Slash		Loblolly		Shortleaf		Pitch	
	Height[z] (g)	Weight (cm)	Height (g)	Weight (cm)	Height (g)	Weight (cm)	Height (g)	Weight (cm)
Control	4.8	0.04	5.1	0.02	3.6	0.01	2.5	0.01
Sticker	4.8	0.03	5.1	0.02	4.1	0.01	2.5	0.01
1% Water Lock	4.7	0.04	4.7	0.02	3.8	0.02	2.9	0.02
Excess Water Lock	4.7	0.03	5.2	0.02	3.7	0.01	2.6	0.01

[z] Heights and dry weights measured 42 days after planting.

intervals. Longleaf pine did germinate at all levels of moisture (Table II-5). Seeds of this species received no stratification. The lower moisture content in the seed at planting time may have allowed better adaptation to dry conditions; however, this difference could also be due to species variation.

There were also no significant effects of coating on the time necessary for 10% or 50% emergence of longleaf pine (Table II-5). In this species, however, those seeds treated with 1% Water Lock generally emerged slightly faster than seeds of other treatments. Seeds exposed to no adhesive or hydrophilic gel (Control) were slowest to emerge except in the 3 day irrigation treatment. The Water Lock coating may have provided enough moisture to slightly enhance emergence rates, but this difference was not statistically significant. As was evident in other pine species, there was no effect of seed coating on seedling dry weights (Table II-5).

Germination rate and seedling dry weights of longleaf pine responded to the various moisture levels (Table II-5). As might be expected, those seeds exposed to the least fluctuation in moisture availability (3 day irrigation intervals) emerged more rapidly and had significantly higher dry weights than seeds exposed to longer periods between irrigations. Seeds subjected to 9 day intervals between irrigations were significantly slower in emerging than those subjected to 3 or 6 day intervals. The significantly slower emergence and lower dry weights of plants irrigated at 6 and 9 day intervals

Table II-5. Average time to 10 and 50 percent emergence and dry weights of longleaf pine. Seeds were treated with a hydrophilic gel and irrigated at 3, 6, or 9 day intervals. There were no statistical differences between gel treatments within each measurement parameter and irrigation interval (F-test).

	10% Emergence			50% Emergence			Dry Weight (g)[y]		
Treatment	3 day	6 day	9 day	3 day	6 day	9 day	3 day	6 day	9 day
Control	13.3	19.1	33.5	20.3	33.3	63.3	0.08	0.04	0.02
Sticker	13.5	16.1	31.1	19.7	25.6	40.8	0.07	0.04	0.03
1% Water Lock	12.0	15.4	29.3	19.8	25.3	38.2	0.08	0.04	0.03
Excess Water Lock	13.7	17.6	29.7	20.1	28.7	49.6	0.07	0.04	0.03
Overall Average	13.1b[z]	17.6b	30.9a	20.0b	28.2b	48.0a	0.08a	0.04b	0.03b

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within measurement parameters followed by the same letter are not significantly different.

[y] Dry weights measured 42 days after planting.

indicates that they were adversely affected by drought stress. This stress was apparently not decreased by hydrophilic gels, since emergence and dry weights were not significantly different regardless of presence or absence of the gel.

Although the deciduous trees were more tolerant to dry conditions than were the pines, there were differences among the species. Adequate moisture was present at 3 and 6 day irrigation intervals for germination and seedling growth of common honeylocust and black locust (Tables II-6 and II-7). Emergence was not apparent for either species at 9 day irrigation intervals. In contrast, Kentucky coffeetree germinated and grew at all irrigation frequencies.

Similar trends occurred with the deciduous species as with the pines. There were no significant differences among seed coatings in the time required for 10% or 50% emergence as calculated by nonlinear regression analysis ($Y = m \log X + b$) of common honeylocust, black locust or Kentucky coffeetree (Tables II-6, II-7, and II-8) within each irrigation interval. Trends, however, varied among the species. The seeds of black locust which were not treated with adhesive or hydrophilic gel consistently emerged more rapidly than treated seeds (Table II-7); although, common honeylocust (Table II-6) showed no consistent trends for rapidity of germination among treatment groups. Although the difference in was not statistically significant, there was some indication that the adhesive may have caused a delay in emergence. This trend was not apparent in Kentucky coffeetree (Table II-8) where the hydrophilic gel-treated seeds emerged more rapidly under all

Table II-6. Average time for 10 and 50 percent emergence, heights, and dry weights of common honeylocust. Seeds were coated with a hydrophilic gel and irrigated at 3 or 6 day intervals. There were no statistical differences between gel treatments within any measurement parameter or irrigation interval (F-test).

	10% Emergence		50% Emergence		Height (cm)[y]		Weight (g)	
Treatment	3 day	6 day	3 day	6 day	3 day	6 day	3 day	6 day
Control	7.7	8.1	12.5	23.7	10.7	9.3	0.14	0.13
Sticker	7.0	6.2	13.3	18.6	11.6	8.6	0.16	0.13
1% Water Lock	5.4	9.4	13.7	18.0	11.1	8.3	0.16	0.10
Excess Water Lock	7.3	10.4	18.3	21.1	10.4	8.4	0.16	0.10
Overall Average	6.8a[z]	8.5a	14.4b	20.4a	11.0a	8.6b	0.16a	0.12b

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within measurement parameters followed by the same letter are not significantly different.

[y] Heights and dry weights were measured 28 days after planting.

Table II-7. Average time for 10 and 50 percent emergence, heights and dry weights of black locust in which seeds were coated with two concentrations of a hydrophilic gel and irrigated at 3 or 6 day intervals. There were no statistical differences between gel treatments within any measurement parameter or irrigation interval (F-test).

	10% Emergence		50% Emergence		Height (cm)[y]		Weight (g)	
Treatment	3 day	6 day	3 day	6 day	3 day	6 day	3 day	6 day
Control	2.4	5.3	5.7	17.4	4.6	3.0	0.04	0.02
Sticker	4.5	6.0	6.8	29.2	4.5	3.6	0.04	0.04
1% Water Lock	6.1	5.4	8.5	32.4	4.3	3.7	0.04	0.03
Excess Water Lock	4.3	8.7	8.4	34.3	4.3	3.5	0.05	0.04
Overall Average	4.3a[z]	6.4a	7.4b	28.3a	4.4a	3.4b	0.04a	0.03b

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within measurement parameters followed by the same letter are not significantly different.

[y] Heights and dry weights measured 28 days after planting.

Table II-8. Average time for 10 and 50 percent emergence of Kentucky coffeetree in which seeds were coated with two concentrations of a hydrophilic gel and irrigated at 3, 6, or 9 day intervals. There were no statistical differences between gel treatments within any measurement parameter or irrigation interval (F-test).

	10% Emergence			50% Emergence		
Treatment	3 day	6 day	9 day	3 day	6 day	9 day
Control	11.5	18.0	15.6	15.3	22.7	25.9
Sticker	12.1	16.0	13.8	15.6	21.8	20.4
Excess Water Lock	8.6	15.5	12.7	12.9	20.9	17.1
Overall Average	10.7b[z]	16.5a	14.0a	14.6b	21.8a	21.1a

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within measurement parameters followed by the same letter are not significantly different.

moisture conditions than either control or adhesive-treated seeds. This increased rate of emergence was not statistically significant, however.

When the emergence rates between irrigation intervals were compared within each species, common honeylocust and black locust followed similar patterns (Tables II-6 and II-7). As would be expected, a longer time period was necessary to attain a particular level of emergence with lower moisture levels. The seeds irrigated at 6 day intervals were significantly slower to attain 50% emergence than were those irrigated at 3 day intervals; although, the difference in time needed for 10% emergence was not significant.

Kentucky coffeetree seeds watered at 6 or 9 day intervals were significantly slower to emerge than those watered at 3 day intervals. The significantly longer emergence time and decreased heights and dry weights of plants irrigated at 6 or 9 day intervals again indicates that plants were adversely affected by drought stress. This stress was apparently not decreased by hydrophilic gel, since emergence and dry weights were not significantly different regardless of presence or absence of the gel.

Seed coating caused no statistically significant differences in seedling heights or dry weights within each deciduous hardwood species and irrigation interval (Tables II-6, II-7, and II-9). There also were no trends apparent between the irrigation intervals of each species. There were, however, significant differences in heights and dry weights

Table II-9. Average heights and dry weights of Kentucky coffeetree. Seeds were treated with a hydrophilic gel and irrigated at 3, 6, or 9 day intervals. There were no statistical differences between gel treatments within either measurement parameter or irrigation interval (F-test).

	Height (cm)[y]			Weight (g)		
Treatment	3 day	6 day	9 day	3 day	6 day	9 day
Control	10.2	10.5	9.8	0.48	0.29	0.25
Sticker	10.6	10.8	10.8	0.51	0.33	0.33
Excess Water Lock	10.2	10.8	10.8	0.49	0.33	0.34
Overall Average	10.3a[z]	10.7a	10.5a	0.49a	0.32b	0.31b

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within measurement parameters followed by the same letter are not significantly different.

[y] Heights and dry weights measured 28 days after planting.

between the irrigation intervals regardless of coating for all species. Again, as anticipated, increased periods between irrigations resulted in significantly decreased heights and dry weights of common honeylocust (Table II-6) and black locust (Table II-7). Dry weights of Kentucky coffeetree (Table II-9) were also significantly less for plants irrigated at 6 and 9 day intervals than at 3 day intervals, but there were no differences between the 6 and 9 day intervals. The heights of Kentucky coffeetree were not significantly different regardless of moisture level.

The deciduous hardwood species were similar to longleaf pine in that they were more tolerant to lower moisture levels in greenhouse studies. These species did not require stratification prior to seed germination, but required scarification prior to moisture imbibition. This difference in pregermination requirements from most of the pine species may explain some of the difference in tolerance to moisture stress. Those seeds which have a higher moisture content at planting may require more moisture, or less moisture fluctuation during germination and early seedling growth periods. Similarly, the hard seed coat of these deciduous species may reduce the amount of water lost from the seed under dry conditions.

Field Studies

Seedling emergence in the field was sparse and many seedlings which did emerge did not survive. Data for this study are, therefore, limited. Some evaluation of performance was possible for deciduous hardwoods.

As in previous studies, there were no significant differences between treatments in number of days to 10% and 50% emergence of common honeylocust and Kentucky coffeetree (Table II-10). Emergence was delayed due to field environmental conditions, as the average number of days to each emergence level was greater than those of corresponding treatments in greenhouse studies (Tables II-6 and II-8). This delay could be due to lower moisture levels in the field than in the greenhouse. Within 24 hours after planting, 0.41 cm of rain fell; however, no precipitation occurred during the following eight days (Appendix 1). There was also no significant difference between the shoot dry weights among the coatings in either species (Table II-10).

CONCLUSIONS

These studies suggest that hydrophilic gels applied as seed coatings have few beneficial effects on seedling emergence, survival, or growth. The rate of emergence varied slightly among treatments within each species and moisture level; however, these differences were statistically insignificant, and followed no consistent pattern. There were also no significant differences in seedling heights or dry weights as a result of hydrophilic gel coating within each species or moisture stress level.

There were significant differences in the rate of emergence, seedling height and dry weight as a result of irrigation intervals within pine and deciduous hardwood species. These differences were anticipated since increased time periods

Table II-10. Average time for 10 and 50 percent emergence, and shoot dry weights of common honeylocust and Kentucky coffeetree seeds coated with a hydrophilic gel and grown under field conditions. There were no statistical differences between gel treatments within any measurement parameter in either species (F-test).

	Common Honeylocust			Kentucky Coffeetree		
	Emergence			Emergence		
Treatment	10%	50%	Weight (g)^z	10%	50%	Weight (g)
Control	19.5	31.2	0.18	16.2	23.0	0.50
Sticker	14.4	25.2	0.25	18.7	26.8	0.56
1% Water Lock	12.7	31.6	0.22			
Excess Water Lock	17.4	27.6	0.22	20.4	27.6	0.60

between irrigation provide the seedling with lower levels and greater fluctuations in moisture. These conditions undoubtedly contributed to delays in germination and decreased seedling growth.

These varying results occurred under the controlled environment of the greenhouse, but many seeds which were exposed to uncontrolled conditions in the field did not survive. Honeylocust and Kentucky coffeetree (Table II-10) survived, but showed no consistent response to the presence of absence of hydrophilic gel.

CHAPTER III

EFFICACY OF A HYDROPHILIC GEL AS A TRANSPLANT AID

INTRODUCTION

According to manufacturers, hydrophilic gels help decrease transplant recovery time and increase survival. Results of research studies which tested the effects of hydrophilic gels utilized as root dips or medium amendments on transplant establishment and survival have varied (Whitmore, 1982; Hensley and Fackler, 1984; Greenwood, Coorts and Maleike, 1978). The purpose of this study was to evaluate the effect of hydrophilic gels on plant response to moisture stress.

MATERIALS AND METHODS

Greenhouse Studies

Substrate was washed from the roots of Marglobe Large Red Tomato seedlings with four true leaves, and the root systems were dipped in a solution of 7.4 g Terra-sorb/l or water. Seedlings were planted in 15 cm plastic pots containing washed river sand or sand:Haynie very fine sandy loam (1:1 vol./vol.). Plants were also planted in media with 3 kg Terra-sorb/m^3 incorporated uniformly. All treatments were well-watered immediately after transplanting, but received no additional water thereafter. Each treatment was replicated four times.

Leaf water potentials were determined with a pressure chamber (PMS Instrument Co., Corvallis, OR), and were recorded as the pressure in which moisture emerged from the cut surface of the leaf. Stomatal resistances were determined with an LI65 Autoporometer (Lambda Instruments Corp., Lincoln, NE) and adjusted to include temperature differences as suggested by manufacturers[1] during midafternoon for several days immediately following planting.

In another study, tomato plants were placed in sand in 15 cm plastic pots on June 12, 1983, and watered and fertilized with 20-20-20 soluble fertilizer as necessary to promote establishment and growth. Treatments consisted of root dips and a medium-amendment as described for the previous studies. Plants were irrigated for the last time on June 24, 1983, and leaf water potentials and stomatal resistances were determined periodically beginning the following morning.

Field Study

Bareroot Norway maple seedlings (*Acer platanoides* L.) were subjected to the same treatments as previously described for the greenhouse studies. The trees were planted in a prepared field of Haynie very fine sandy loam soil at the Ashland Horticultural Research Farm on June 1, 1983. Average planting hole size was 550 cm^3. The plots received no supplemental fertilizer or irrigation prior to, or after transplanting. Weeds were removed by hand as necessary. Each treatment contained five trees and was replicated four times.

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[1] "Autoporometer LI65 Operator Manual" Lambda Instruments Corp., Lincoln, NE.

Temperature and rainfall data for the experimental period are listed in Appendix 1.

Leaf water potentials and stomatal resistances were measured periodically as described earlier. Visual evaluations were conducted 105 days after planting by two independent evaluators using a scale of 1 to 5. The criteria for the visual rating was as follows: 1 = poor specimen with foliage having widespread necrotic areas, and 5 = excellent specimen with no foliar chlorosis or necrosis. An analysis of variance and mean separations were conducted on all data.

RESULTS AND DISCUSSION

Greenhouse Studies

Factorial analysis of the data from the study in which tomatoes were transplanted into sand indicates that there was a significant effect of the gels on leaf water potentials (Table III-1). Average leaf water potentials of plants, regardless of treatment, decreased significantly between 24 and 48 hours after transplanting. Little change occurred from 48 to 72 hours. Leaf water potentials were expected to decrease throughout the study since soil moisture was lost through evapotranspiration. Although significant differences occurred within both main effects, there were no interactions between time and hydrophilic gel treatment.

Leaf water potential measurements the morning of the second day after transplanting indicated that only slight overnight recovery occurred in control plants (leaf water potential increased from -1.10 MPa to -1.02 MPa) (data not shown).

Table III-1. Leaf water potentials 24, 48, and 72 hours after transplanting and irrigating tomato plants in sand.

Treatment Main Effects	
Treatment	Leaf water potential (-MPa)
Control	1.29b[z]
Media	1.03c
Dip	1.44a
Time Main Effects	
Hours after transplanting	
24	0.98b
48	1.40a
72	1.38a
r[y]=.844	

---

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within each main effect column followed by the same letter are not significantly different.

[y] r = correlation coefficient of leaf water potential vs. time after transplanting. Not significant at 5% level.

This recovery was not statistically significant. In contrast, leaf water potentials of plants exposed to a root dip in Terra-sorb as well as those planted in amended media decreased from -1.22 and -.64 MPa to -1.24 and -1.18 MPa, respectively, indicating increased moisture stress. The decrease in leaf water potential of dipped plants was not statistically significant, but plants in amended sand were more stressed during the morning than during the previous afternoon. Leaf water potentials measured during midafternoon the second day decreased, but not significantly, in plants of all treatment groups.

Plants placed in sand, began to wilt within 48 hours after transplanting regardless of presence or absence of hydrophilic gel. Therefore, a finer-textured medium, sand: very fine sandy loam (1:1 vol./vol.) was used to improve the moisture holding capacity. Plants in this medium began wilting slightly later (within 72 hours) after transplanting.

No significant differences in leaf water potential or stomatal resistance occurred between treatments at any time when planted in the sand:soil mix (Table III-2), and there were no time x treatment interactions. As in the previous study, however, leaf water potential decreased significantly between 24 and 72 hours after transplanting. Linear regression analysis showed a significant (p=1%) linear relationship between time and leaf water potential (r=1.000). Stomatal resistance of all plants, regardless of hydrophilic gel treatment, showed a linear increase between 24 and 96 hours (r=.997).

Table III-2. Leaf water potentials and stomatal resistances of tomato plants exposed to various hydrophilic gel treatments and transplanted into sand: Haynie very fine sandy loam (1:1 vol./vol.).

Treatment	Leaf Water Potential (-MPa)	Stomatal Resistance (sec/cm)
	Treatment Main Effects	
Control	1.24a[z]	27.07a
Media	1.42a	29.46a
Dip	1.18a	28.23a
	Time Main Effects	
Hours after transplanting		
24	0.99b	12.00b
72	1.34a	32.68a
96	1.51a	40.08a
	r[y]=1.000**	r=.997*

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within each main effect column followed by the same letter are not significantly different.

[y] r = correlation coeffieicnt. ** and * significant at 1% and 5%, respectively.

The high correlation between time and leaf water potential suggests that moisture uptake may decrease due to lower moisture availability. Duniway (1971) found that as leaf water potential of tomato leaves decreased, stomatal resistance sharply increased (at approximately 1.0 MPa). Therefore, the high coorelation between time and stomatal resistance is probably a response to the decrease in leaf water potential.

The final greenhouse study differed from the other two studies in that transplants were allowed to establish for two weeks under optimum growing conditions prior to withholding moisture. As in the previous study, there were no statistically significant differences in leaf water potential or stomatal resistances between the treatments, nor interactions between time and treatment main effects (Table III-3).

In prior studies, leaf water potentials significantly decreased with 48 to 72 hours after transplanting, and stomatal resistance significantly increased within 72 hours after transplanting into a sand:soil mix. In established plants, however, leaf water potentials did not significantly decrease until 96 hours after the final irrigation (Table III-3). The linear correlation between time and leaf water potentials was not significant, presumably because of this lag. Stomatal resistance, however, increased in a linear fashion (r=.995) throughout the study.

The delay in response of established plants to lower moisture levels might be expected, since they were able to

Table III-3. Leaf water potentials and stomatal resistances of tomato plants transplanted into sand and allowed to establish for two weeks.

Treatment	Leaf Water Potential (-MPa)	Stomatal Resistance (sec/cm)
	Treatment Main Effects	
Control	1.17a[z]	11.78a
Media	1.16a	11.00a
Dip	1.21a	15.50a
	Time Main Effects	
Hours after irrigation		
24	1.04b	4.18b
72	1.09b	13.48ab
96	1.41a	20.14a
	r[y]=.832	r=.995

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within each main effect column followed by the same letter are not significantly different.

[y] r = correlation coefficient. Not significant at 5% level.

regenerate roots for more extensive moisture uptake prior to the experimental imposition of drought. Most moisture uptake occurs chiefly in the root hair zone (Kramer, 1983). Root hairs are often lost in transplanting, so moisture uptake may be reduced. If plants can regenerate roots prior to the onset of drought conditions, moisture uptake would occur more readily despite lower water availability.

Morning measurements of leaf water potential indicated overnight recovery from moisture stress (Table III-4). Lower stomatal resistances in the morning are indicative of open stomates, but stomatal resistance increased during afternoon measurements.

It is commonly accepted that stomates close in response to moisture stress. There is, evidently, a leaf water potential above which leaf resistance and stomatal opening remain constant (Hsiao, 1973). Once this leaf water potential is reached during imposition of a drought, stomatal resistance sharply increases. This relationship between leaf water potential and stomatal resistance was shown to exist in tomatoes by Duniway (1971). In that study, stomatal resistance sharply increased at about -1.1 MPa. This corresponds with the findings of the present study in which stomatal resistance of established plants increased sharply beginning at -1.0 MPa. Stomatal resistance of new transplants, however, did not sharply increase until exposed to -1.3 to -1.4 MPa of pressure.

Hydrophilic gels have been shown to improve moisture retention of sandy loam and loamy sand soils (Hemyari and

Table III-4: Leaf water potential and stomatal resistance of tomato plants established using hydrophilic gel root dips and a medium amendment. Plants were transplanted on June 12 and last watered on June 24.

Date and Time	Leaf Water Potential (-MPa)			Stomatal Resistance (sec/cm)		
	Control	Media	Dip	Control	Media	Dip
6/25 am	0.55	0.72	0.89	2.41	2.16	4.01
6/25 pm	1.08	0.96	1.09	3.90	2.83	5.83
6/26 am	0.94	0.81	0.85	2.85	1.55	1.85
6/27 pm	1.05	1.12	1.10	15.30	16.10	9.10

Nofziger, 1981). This improved moisture retention may enhance the ability of the soil to store water for plant use. Improved moisture utilization may account for the higher leaf water potential of plants exposed to amended media in the initial study reported in this chapter.

The results of these studies agree with other studies in which hydrophilic gels were incorporated into the medium of container-grown plants. The time required for wilting of marigold (Tagetes erecta L.) and zinnia (Zinnia elegans Jacq.) was increased, and moisture stress decreased, with the incorporation of a hydrophilic gel into Jiffy Mix (Gehring and Lewis, 1980). Hydrophilic gel also reduced the number of waterings necessary for growth of chrysanthemum (Chrysanthemum morifolium Ramat.) in hardwood bark media (Still, 1976).

There have also been reports that hydrophilic gels applied as a root dip might improve transplant establishment (Whitmore, 1982; Deterling, 1981); however, Hensley and Fackler (1984) found no significant difference in survival or growth of winter jasmine (Jasminium nudiflorum Lindl.) or purple-leaf wintercreeper (Euonymous fortunei Turcz. 'Colorata') regardless of root dip treatment. The results of the present study resemble those of Hensley and Fackler (1984), since plant survival and growth were not improved with root dips. Instead, plant water potentials of dipped plants in sand were significantly lower than those of controls (Table III-1). In contrast, leaf water potentials of plants exposed to root dips was slightly greater than control plants in the finer-textured media (Table III-2 and III-3); although, these differences were not significant.

Tha apparent conflict between studies reported in this chapter and other reports may be attributed to differences in the control treatments. Previous studies compared plants which had been dipped in hydrophilic gels to undipped control plants (Whitmore, 1982; Deterling, 1981). Controls in present studies were placed in water prior to planting. Better survival and growth of controls in these studies should have occurred due to the presence of moisture prior to planting. The probable improved performance of controls may decrease observable differences between control and dipped plants. Similarly, wide variations in data from all treatments in these studies may have masked any real differences between the treatment groups.

These studies indicate that the incorporation of hydrophilic gels into media with low water holding capacity may delay the effects of a reduced moisture level on new transplants by a few hours. The hydrophilic material had no effect, however, on transplants placed in soils with a higher water holding capacity or those which were allowed to establish prior to the onset of low moisture conditions. Media amendments were also found to be more effective than root dips in providing moisture to the plant. Roots dipped in hydrophilic gels tend to mat together, reducing the root area exposed to soil moisture. This may be one explanation for the lower performance of dipped plants than those exposed to amended media.

As was anticipated, leaf water potentials decreased and stomatal resistances increased with time in all studies. The changes in leaf water potential were delayed in plants which were allowed to establish prior to imposing stress. This was likely due to the regeneration of roots, enabling more extensive moisture uptake.

Field Study

There were no statistical differences in leaf water potential or stomatal resistance among the various hydrophilic gel treatments in maples (Table III-5). Leaf water potentials, however, varied with sampling date. There were no significant differences in stomatal resistances throughout the study period and no interactions occurred between the various hydrophilic gel treatments and time from transplanting in either parameter.

The general condition of plants in all treatments and replications deteriorated due to the excessive heat and drought of the growing season. The average visual ratings (1 = poor, 5 = excellent) were 2.87 for control plants, 2.67 for plants in amended backfill and 2.57 for root dipped plants. There were no statistical differences in these visual ratings. Maples are susceptable to leaf scorch during periods of moisture stress, and necrotic foliar edges were equally present in all treatments. The addition of gel as a medium amendment or root dip did not apparently improve soil moisture levels sufficiently to avoid foliar damage.

Table III-5. Leaf water potentials and stomatal resistances of maples transplanted utilizing hydrophilic gel root dips and medium amendments.

Treatment	Leaf Water Potential (-MPa)	Stomatal Resistance (sec/cm)
	Treatment Main Effects	
Control	2.44a[z]	7.41a
Media	2.38a	5.58a
Dip	2.36a	5.59a
	Time Main Effects	
Days from Transplanting		
36	2.33ab	5.47a
43	2.49a	5.72a
49	2.56a	8.87a
56	2.13b	7.83a
62	2.56a	
71	2.30ab	7.60a

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within each main effect column followed by the same letter are not significantly different.

CONCLUSIONS

Plants which were placed in sand amended with Terra-sorb had significantly higher (less negative) plant water potentials than those exposed to a Terra-sorb root dip or untreated plants (Table III-1). Hydrophilic gels may improve the moisture holding capacity of soils (Bearce and McCollum, 1977; Conover and Poole, 1976), but this improvement apparently lasts only a short time during increasing drought stress.

There was no significant difference in leaf water potential or stomatal resistance of plants planted in a finer-textured media or when plants were allowed to establish before inducing moisture stress (Tables III-2, III-3). Without addition of moisture, leaf water potentials decreased and stomatal resistance increased in tomatoes regardless of treatment.

There were also no significant differences in leaf water potential or stomatal resistance among treatments of field planted maples (Table III-5). Leaf water potential did vary with sampling date throughout the study but no correlation to, or interaction with, treatment were apparent. Midday stomatal resistance did not change significantly throughout the period.

Hydrophilic gels apparently must be incorporated into the media to impart even a transient advantage to transplants. Such incorporation is not generally feasible from an operations standpoint, especially considering the small likelihood of benefit. Media incorporation may however, provide some advantage in containerized plant production. Indeed, increased plant height (Bearce and McCollum, 1977; Conover and Poole, 1976) and reduced irrigation requirements (Gehring and Lewis, 1979, 1980) have been recorded. Based on the results reported here, however, there are no apparent long-term plant or economic advantages in field operations.

CHAPTER IV

RETENTION OF AMMONIUM, NITRATE AND HERBICIDES BY A HYDROPHILIC GEL

INTRODUCTION

Hydrophilic gels have been shown to absorb many times their weight in moisture, then release it to the environment as it becomes dry (Alston, 1982). A question arises regarding their ability to absorb other compounds. The purpose of these studies was to determine whether ammonium, nitrate, or herbicides are absorbed and retained by hydrophilic gels.

MATERIALS AND METHODS

Ammonium or Nitrate Retention

Silica sand was amended with 0, 2, 3, and 4 kg Water Lock B100 Absorbent Starch/m^3. Ten cm plastic pots were filled with 400 cm^3 of the various sand-hydrophilic gel mixtures. Two groups, each with three replications of each hydrophilic gel treatment were prepared. One group of treatments was saturated with distilled water to allow hydration of the hydrophilic gel, while the other group remained dry.

Ammonium nitrate (58 ppm ammonium and 200 ppm nitrate) was applied to each pot in 200 ml of distilled water. The excess solution was collected and ammonium content determined using an Orion ammonia ion electrode (Orion Research Inc., Cambridge, Mass.). Nitrate content of leachate was determined with an Altex nitrate electrode (Beckman Instruments, Inc., Irvine, Calif.) in conjunction with an Orion reference electrode. An Orion Model 701A digital pH/mv meter (Orion Research, Inc., Cambridge, Mass.) was utilized for all measurements.

After collection and measurement of excess ammonium nitrate solution, each pot was leached with distilled water until 100 ml of leachate was collected four times. Ammonium and nitrate content of each leachate collection was determined. Analysis of variance and mean separations were performed on all data.

Herbicide Retention

Silica sand was amended with Water Lock B100 Absorbent Starch as in the previous study. Ten cm pots were filled with 500 g of the various sand-hydrophilic gel mixtures. Napropamide (2-(a-naphthoxyl)-N,N-diethylpropionamide) and simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) were applied at rates of 1 ppm and 2 ppm respectively to appropriate groups of amended pots. A third group of pots received no herbicide application. These herbicides were utilized because of their retention characteristics in sandy soils. Napropamide is apparently resistant to leaching in most soil types (Mullison, et al,, 1979); whereas, simazine is more readily leached from sandy soils than from finer textured or organic soils (Doherty and Warren, 1969).

After herbicide application, both herbicide treatment groups and the controls were leached with 1000 ml of water.

eight pregerminated oat (Avena sativa L.) seeds were planted in each pot. Seedlings were irrigated at 3 day intervals with 150 ml of water, and 20-20-20 soluble fertilizer was applied as necessary to maintain seedling growth. After two weeks, total emergence and seedling heights of herbicide treatments were recorded and compared to that of appropriate controls. Data were evaluated through factorial analysis of variance and mean separation procedures.

RESULTS AND DISCUSSION

Ammonium or Nitrate Retention

Analysis of the leachate from the various amended media indicated that ammonium applied to water-saturated treatments was retained (Figure IV-1). This retention occurred despite several washes with distilled water, and increased with increasing concentrations of Water Lock. The greatest release of ammonium occurred with the first leaching of the 1 and 2 kg/m^3 treatments, and small amounts were released from the media with each successive wash. Retention by 2 kg Water $Lock/m^3$ was consistently, but not significantly greater than that of unamended sand. Sand amended with 3 kg Water Lock and 4 kg Water $Lock/m^3$ absorbed significantly more ammonium than unamended sand.

In dry media to which ammonium was added, more than 85% of the total ammonium added was retained in all amended media, regardless of the rate, while only 25% was retained in unamended sand (Figure IV-2).

Figure IV-1. Ammonium retention (%) by silica sand amended with 0, 2, 3, and 4 kg hydrophilic gel/m^3 and saturated with distilled water prior to ammonium nitrate application and leaching with distilled water. Vertical bars represent statistical significance (Tukey's HSD Procedure, 5%).

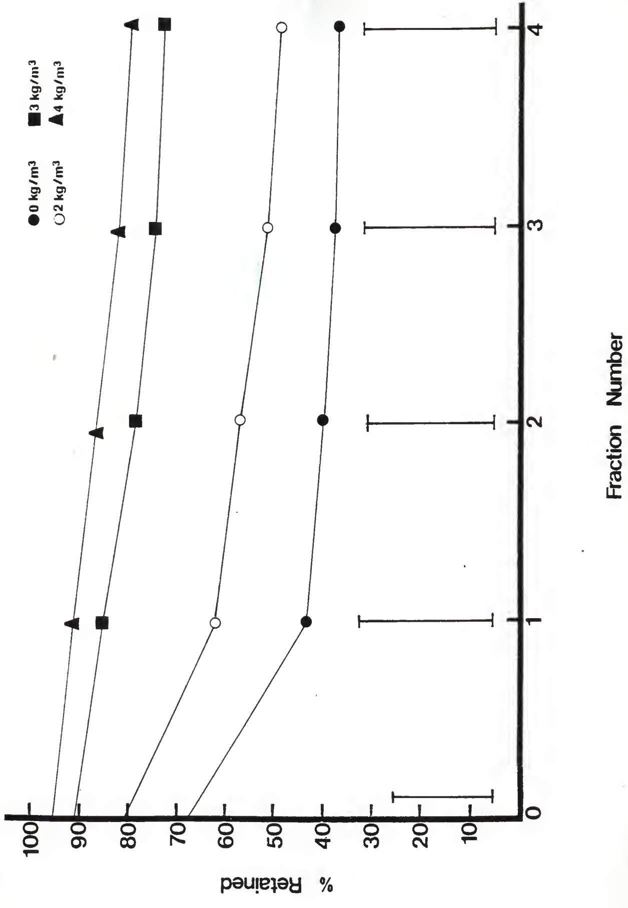
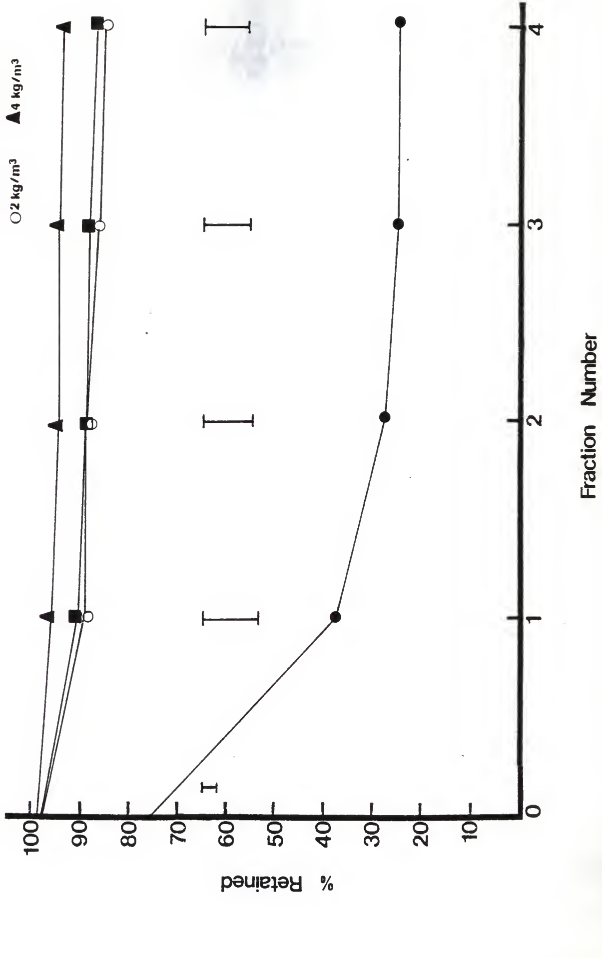

● 0 kg/m³
○ 2 kg/m³
■ 3 kg/m³
▲ 4 kg/m³
% Retained
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
Fraction Number

Figure IV-2. Ammonium retention (%) by silica sand amended with 0, 2, 3, and 4 kg dry hydrophilic gel/m^3, prior to ammonium nitrate application and leaching with distilled water. Vertical bars represent statistical significance (Tukey's HSD Procedure, 5%).


% Retained
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
Fraction Number
● 0 kg/m^3
○ 2 kg/m^3
■ 3 kg/m^3
▲ 4 kg/m^3

Much more ammonium was retained by unhydrated hydrophilic gel than by hydrated at the 2 kg Water Lock/m^3 rate. The 3 kg and 4 kg Water Lock/m^3 rates retained more ammonium when unhydrated than hydrated (Figures IV-1, IV-2); however, the difference was not as pronounced. The greater retention of ammonium by unsaturated, amended media may indicate that many absorption sites were unavailable to ammonium when the gel was hydrated. If few absorption sites were available, ammonium could have moved through the hydrated media more readily.

In contrast to ammonium, nitrate was rapidly lost from hydrated media regardless of the presence or absence of hydrophilic gel (Figure IV-3). Eighty-three percent or more of the nitrate was lost from all treatments by the third leaching. There were no significant differences in the amount of nitrate retained by any media amendment.

Nitrate applied to dry media was again readily leached (Figure IV-4). Significantly more nitrate was retained by all amended media than by sand alone at the initial application. This retention was apparently due to the higher absorption capacity of the amended media. Upon the first leaching with water, however, the amount retained by 2 kg Water Lock and 3 kg Water Lock/m^3 was not significantly greater than retention by sand alone; whereas the 4 kg Water Lock/m^3 retained significantly more nitrate than sand. After a second and all subsequent leachings, there was no statistical difference in retention of nitrate by any media.

Figure IV-3. Nitrate retention (%) by silica sand amended with 0, 2, 3, and 4 kg hydrophilic gel/m^3 and saturated with distilled water prior to ammonium nitrate application and leaching with distilled water. There were no significant differences in retention among hydrophilic gel concentrations at each leaching (F-test).

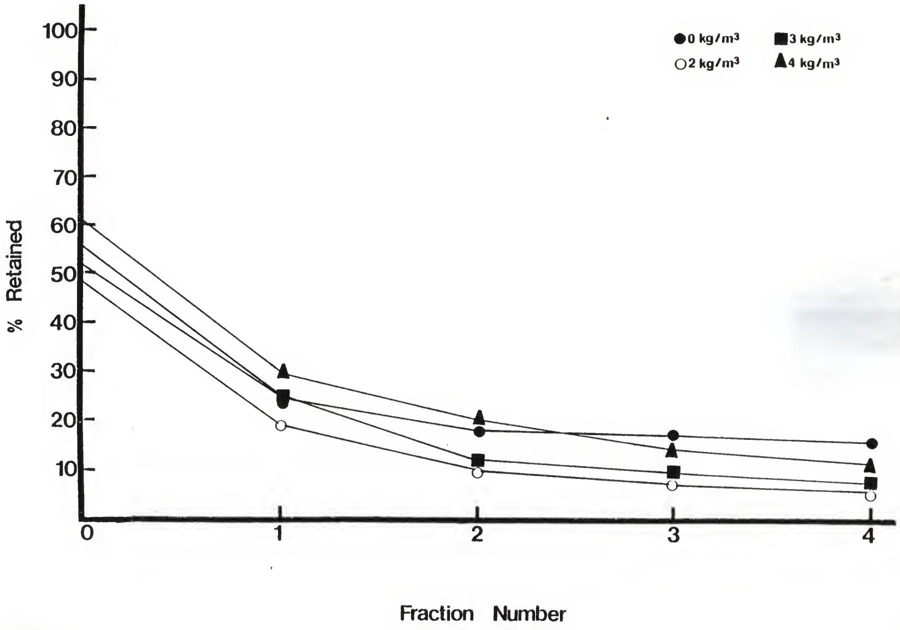
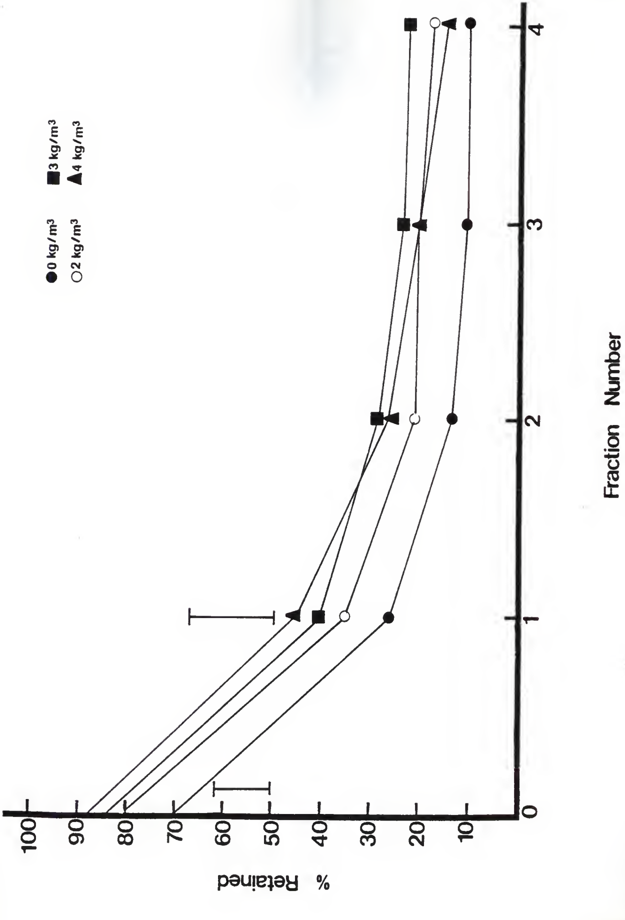

● 0 kg/m³
■ 3 kg/m³
○ 2 kg/m³
▲ 4 kg/m³
100
90
80
70
60
50
40
30
20
10
% Retained
0
1
2
3
4
Fraction Number

Figure IV-4. Nitrate retention (%) by silica sand amended with 0, 2, 3, and 4 kg hydrophilic gel/m^3, prior to ammonium nitrate application and leaching with distilled water. Vertical bars represent statistical significance (Tukey's HSD Procedure, 5%).


● 0 kg/m³
○ 2 kg/m³
■ 3 kg/m³
▲ 4 kg/m³
% Retained
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
Fraction Number

Behavior of ammonium and nitrate in these various sand and hydrophilic gel mixtures was similar to that expected in soil. Positively charged ammonium ions are readily absorbed and retained by negatively charged surfaces of clay or organic particles. The ionic attraction causes the ammonium ion to be less subject to leaching in soils. The lower cation exchange capacity of sand allows more ammonium to leach from it. In contrast, nitrate is very mobile and leaches readily through all soils (Tisdale and Nelson, 1975; Donahue, Miller and Shickluna, 1977).

Little information is available on the retention of nutrients by hydrophilic gels. Taylor and Halfacre (1983) reported a possible interaction between hydrophilic gel and nutrients resulting in increased growth of Ligustrum ludicum Ait. 'Compactum'. Other gel materials are frequently used in fluid drilling pregerminated seeds.

Nitrogen, phosphorus, and potassium fertilizers incorporated into a guar gum gel decreased emergence of fluid-drilled lettuce (Lactuca sativa L.) (Costigan and Locascio, 1982). This decrease was attributed to high salinity. When fertilizer treatments were decreased to reduce salinity, the nutrient addition was found to be too low to affect growth.

In another study, Hoagland's solution was applied in magnesium silicate gel and resulted in reduced emergence of tomatoes (Pill and Watts, 1983). This was again attributed to low osmotic potential. Finch-Savage and Cox (1982) added phosphate to guar gum and magnesium silicate gel, used to fluid drill carrot seedlings. The added phosphate improved plant growth; however, high levels were toxic.

Herbicide Retention

Factorial analysis of survival and growth data showed no interaction between the hydrophilic gel rates and addition of simazine or napropamide. There were, however, differences in plant response to the presence or absence of herbicides as well as to various concentrations of hydrophilic gels (Tables IV-1, IV-2).

Simazine was apparently leached from all pots regardless of the rate of hydrophilic gel amendment (Table IV-1). Although survival of oats placed in media to which 1 ppm simazine had been applied was less than that of controls, this difference was not statistically significant. Plant heights in simazine-treated media were 12% less than controls. This difference, although not statistically significant, indicates that simazine was present, but not in large enough quantities to affect plant growth. Simazine is a photosynthetic inhibitor which controls both grass and broadleaved seedlings (Anderson, 1977).

Analysis of gel rate main effects showed that both survival and especially plant heights decreased with increasing concentrations of hydrophilic gels ($r=-.956$ and $-.962$, respectively) (Table IV-1). Survival was not significantly reduced by any gel rate, but plant heights in the 3 and 4 kg/m^3 treatments were significantly less than those in unamended

Table IV-1. Percent survival and average heights (cm) of oats exposed to various concentrations of a hydrophilic gel as a medium amendment and simazine.

Treatment	Survival (%)	Height (cm)
	Herbicide Main Effects	
Control	97.92a[z]	1.54a
Simazine	93.75a	1.36a
	Gel Main Effects	
Rate (kg/m^3)		
0	97.92a	1.94a
2	95.83a	1.69ab
3	95.83a	1.19bc
4	93.75a	0.96c
	r[y]=-.956	r=-.962

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within each main effect column followed by the same letter are not significantly different.

[y] r = correlation coefficient.

Table IV-2. Percent survival of oats exposed to various concentrations of a hydrophilic gel as a medium amendment and napropamide.

Treatment	Survival (%)
Herbicide Main Effects	
Control	97.92a[z]
Napropamide	22.92b
Gel Main Effects	
Rate (kg/m^3)	
0	77.08a
2	64.58a
3	47.92a
4	52.08a
	r[y]=-.926

[z] Mean separation utilizing Tukey's HSD procedure, 5% level. Means within each main effect column followed by the same letter are not significantly different.

[y] r = correlation coefficient.

sand. Seedling heights in the 4 kg/m^3 amendment were also significantly less than in the 2 kg/m^3 treatment.

In contrast to simazine, napropamide caused a marked decrease in survival of pregerminated seedlings (Table IV-2). Napropamide was retained at lethal levels regardless of the presence or absence of hydrophilic gel. Since survival was greatly limited by napropamide addition, analysis of seedling heights was not feasible. Napropamide inhibits root growth and development of grasses (Anderson, 1977).

In these studies, however, 1 ppm simazine was not retained by any media in amounts that would cause a significant decrease in seedling survival and growth. Oats have been shown to be quite sensitive to 0.75 to 1.5 ppm simazine in a soil system (Chadwick and Reisch, 1961). Napropamide was apparently retained at lethal levels even in unamended sand.

Simazine, a triazine, is readily adsorbed to soil colloids and tends to resist leaching (Anderson, 1977). Increasing the concentration of simazine applied may have resulted in different findings. Larger amounts may have been retained by the media, and survival and growth might have been reduced. In contrast, napropamide resists leaching in most mineral soils. Adequate quantities were retained to affect seedling survival.

Increasing hydrophilic gel concentrations also slightly decreased seedling survival and significantly reduced seedling heights. Manufacturers recommend rates of 2 to 3 kg hydrophilic gel/m^3[1]. Therefore, the 4 kg/m^3 amendment utilized in these studies was higher than normal. Decreased viability of snapdragon (Antirrhinum majus L.) seedlings after storage in hydrophilic gels has been attributed to lower oxygen diffusion rates in the hydrophilic gels (Frazier, Wiest and Wootton, 1982). Reduced aeration of sand amended with increasing concentrations of hydrophilic gel may also explain decreases in survival and growth in this study, especially at higher amendment rates.

Plants have been grown in other medias amended with hydrophilic materials without deleterious effects. Bearce and McCollum (1977) found growth of chrysanthemum, Easter lily and tomatoes actually increased in a peat-lite medium and a bark mix amended with Viterra 2 Hydrogel. This increase was probably due to improved media water relations with normal hydrophilic gel rates.

CONCLUSIONS

The results of this study may be of importance to container producers who utilize artificial medias. Improved plant water relations and a corresponding increase in plant growth have resulted from media amended with hydrophilic gel materials (Gehring and Lewis, 1979, 1980; Bearce and McCollum, 1977; Greenwood, Coorts and Maleike, 1978). Plants responded to increased moisture, and the corresponding decrease in media aeration apparently had little effect. Amendment rates in

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[1] "Horticultural and Agricultural Uses for Water Lock Superabsorbent" Product Bulletin #8032. Grain Processing Corporation, Muscatine, IA.

these studies were also less than or equal to the 2 to 3 kg/m^3 rates recommended by manufacturers.

The addition of hydrophilic gels to media may influence their nutrient retention abilities. Fertilizer programs may need to be altered to reflect this. Those media with low absorption capabilities, such as pine bark and inert aggregates, would likely retain greater amounts of ammonium and likely phosphorus and potassium. Although not tested, this assumption might be generally extrapolated from similar performance of these elements in soil systems (Tisdale and Nelson, 1975).

The influence of herbicides on plant survival and growth in this study, was not altered by the presence or absence of hydrophilic gels. There should, therefore, be little influence of hydrophilic gels on the effectiveness of these herbicides at normal rates. Other herbicides utilized in conjunction with hydrophilic gels may cause different plant responses than when utilized without hydrophilic gels. Herbicide effects with hydrophilic gels should be tested prior to widespread utilization.

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APPENDIX I

Temperatures and Precipitation recorded by
Kansas State University Physics Department

Date	Temperature (^{o}F)		Precipitation (in)
	High	Low	
May 23	76	43	
24	84	51	0.16
25	72	53	
26	78	48	
27	87	57	
28	87	59	
29	71	49	
30	67	46	
31	68	43	
June 1	68	43	
2	65	58	0.04
3	80	57	0.35
4	84	51	
5	65	50	0.04
6	74	45	
7	79	49	
8	82	50	
9	84	61	
10	71	64	0.24
11	76	64	
12	83	68	
13	80	59	1.46
14	79	54	
15	85	58	
16	82	59	
17	84	58	
18	85	61	0.04
19	90	67	
20	90	71	
21	90	69	
22	92	68	
23	91	66	
24	90	65	0.16
25	87	68	0.71
26	81	67	
27	81	63	0.51
28	85	65	0.04
29	86	66	0.20
30	95	69	

	Temperature (°F)		Precipitation (in)
Date	High	Low	
July 1	95	75	
2	92	73	
3	99	72	
4	86	65	
5	85	62	
6	86	57	
7	87	64	
8	89	68	
9	90	65	
10	93	67	
11	98	71	
12	96	66	
13	91	68	
14	89	74	
15	86	69	
16	86	71	
17	91	70	
18	99	74	
19	101	77	
20	99	77	
21	101	78	
22	103	75	
23	104	76	
24	96	70	
25	90	64	
26	94	64	
27	106	75	
28	105	78	
29	101	76	
30	100	72	
31	99	71	0.55
August 1	102	67	
2	102	77	
3	102	77	
4	97	79	
5	101	76	
6	91	73	0.12
7	96	67	
8	97	66	
9	99	67	
10	100	74	
11	95	70	
12	93	61	
13	97	64	
14	90	69	0.12
15	101	70	
16	107	79	
17	107	82	

Date	Temperature (^{o}F) High	Low	Precipitation (in)
August 18	101	78	
19	99	75	
20	82	72	0.51
21	98	74	
22	91	75	
23	97	70	0.28
24	97	72	
25	102	73	
26	102	73	
27	100	74	
28	98	74	
29	95	73	0.04
30	90	75	
31	92	67	

APPENDIX II

ANALYSIS OF VARIANCE TABLES

Table	Treatment	F	Treatment df	Error df	p
II-1	Bean, sand, 10%	0.76	5	10	0.60
II-1	Bean, sand, 50%	2.59	5	10	0.09
II-1	Pea, sand, 10%	2.20	5	10	0.14
II-1	Pea, sand, 50%	0.98	5	10	0.48
II-1	Tomato, sand, 10%	3.03	5	10	0.06
II-1	Tomato, sand, 50%	2.80	5	10	0.08
II-1	Okra, sand, 10%	0.73	5	10	0.62
II-1	Okra, sand, 50%	0.94	5	10	0.06
II-1	Bean, JM, 10%	0.87	5	10	0.53
II-1	Bean, JM, 50%	2.00	5	10	0.16
II-1	Pea, JM, 10%	2.20	5	10	0.14
II-1	Pea, JM, 50%	3.18	5	10	0.06
II-1	Tomato, JM, 10%	1.52	5	10	0.27
II-1	Tomato, JM, 50%	0.62	5	10	0.69
II-2	Bean, sand, wt.	1.07	5	10	0.43
II-2	Pea, sand, ht.	1.15	5	10	0.40
II-2	Pea, sand, wt.	1.27	5	10	0.35
II-2	Tomato, sand, ht.	2.00	5	10	0.16
II-2	Tomato, sand, wt.	1.28	5	10	0.34
II-2	Okra, sand, ht.	1.43	5	10	0.29
II-2	Okra, sand, wt.	2.43	5	10	0.11
II-2	Bean, JM, wt.	1.93	5	10	0.18
II-2	Pea, JM, ht.	2.83	5	10	0.08
II-2	Pea, JM, wt.	1.44	5	10	0.29
II-2	Tomato, JM, ht.	0.37	5	10	0.86
II-2	Tomato, JM, wt.	2.39	5	10	0.11
II-3	Slash, 10%	4.30	3	6	0.06
II-3	Slash, 50%	2.42	3	6	0.16
II-3	Loblolly, 10%	3.05	3	6	0.11
II-3	Loblolly, 50%	0.50	3	6	0.70
II-3	Shortleaf, 10%	4.66	3	6	0.05
II-3	Shortleaf, 50%	2.24	3	6	0.18
II-3	Pitch, 10%	1.53	3	6	0.30
II-3	Pitch, 50%	1.87	3	6	0.24

Table	Treatment	F	Treatment df	Error df	p
II-4	Longleaf, 10%, 3	0.25	3	6	0.86
II-4	Longleaf, 10%, 6	0.51	3	6	0.69
II-4	Longleaf, 10%, 9	0.80	3	6	0.54
II-4	Longleaf, 50%, 3	0.03	3	6	0.99
II-4	Longleaf, 50%, 6	0.50	3	6	0.70
II-4	Longleaf, 50%, 9	4.29	3	6	0.06
II-4	Longleaf, Wt., 3	0.11	3	6	0.95
II-4	Longleaf, Wt., 6	0.60	3	6	0.64
II-4	Longleaf, Wt., 9	0.49	3	6	0.70
II-4	Longleaf, 10%, Irr.	321.50	2	6	0.00
II-4	Longleaf, 50%, Irr.	25.80	2	6	0.00
II-4	Longleaf, Wt., Irr.	97.00	2	6	0.00
II-5	Slash, ht.	0.31	3	6	0.82
II-5	Slash, wt.	0.41	3	6	0.75
II-5	Loblolly, ht.	3.51	3	6	0.09
II-5	Loblolly, wt.	0.54	3	6	0.67
II-5	Shortleaf, ht.	0.25	3	6	0.86
II-5	Shortleaf, wt.	1.13	3	6	0.41
II-5	Pitch, ht.	3.22	3	6	0.10
II-5	Pitch, wt.	3.74	3	6	0.08
II-6	Honeylocust, 10%, 3	0.56	3	6	0.66
II-6	Honeylocust, 10%, 6	6.20	3	6	0.03
II-6	Honeylocust, 50%, 3	0.51	3	6	0.69
II-6	Honeylocust, 50%, 6	1.67	3	6	0.27
II-6	Honeylocust, ht., 3	12.18	3	6	0.01
II-6	Honeylocust, ht., 6	1.46	3	6	0.32
II-6	Honeylocust, wt., 3	0.75	3	6	0.56
II-6	Honeylocust, wt., 6	4.81	3	6	0.05
II-6	Honeylocust, 10%, Irr.	2.22	1	3	0.23
II-6	Honeylocust, 50%, Irr.	6.78	1	3	0.08
II-6	Honeylocust, ht., Irr.	38.71	1	3	0.01
II-6	Honeylocust, wt., Irr.	10.70	1	3	0.05
II-7	Black locust,10%, 3	4.05	3	6	0.06
II-7	B.L., 10%, 6	0.67	3	6	0.60
II-7	B.L., 50%, 3	0.83	3	6	0.52
II-7	B.L., 50%, 6	0.66	3	6	0.60
II-7	B.L., ht., 3	0.85	3	6	0.52
II-7	B.L., ht., 6	0.81	3	6	0.53
II-7	B.L., wt., 3	0.17	3	6	0.91
II-7	B.L., wt., 6	1.58	3	6	0.29
II-7	B.L., 10%, Irr.	3.49	1	3	0.16
II-7	B.L., 50%, Irr.	43.68	1	3	0.01
II-7	B.L., ht., Irr.	20.10	1	3	0.02
II-7	B.L., wt., Irr.	6.00	1	3	0.09

Table	Treatment	F	Treatment df	Error df	p
II-8	Kentucky coffeetree 10%, 3	1.41	2	4	0.34
II-8	K.C., 10%, 6	1.68	2	4	0.30
II-8	K.C., 10%, 9	1.41	2	4	0.34
II-8	K.C., 50%, 3	1.18	2	4	0.40
II-8	K.C., 50%, 6	0.18	2	4	0.84
II-8	K.C., 50%, 9	3.93	2	4	0.11
II-8	K.C., 10%, Irr.	32.29	2	4	0.00
II-8	K.C., 50%, Irr.	10.96	2	4	0.02
II-9	K.C., ht., 3	0.88	2	4	0.48
II-9	K.C., ht., 6	0.30	2	4	0.76
II-9	K.C., ht., 9	1.17	2	4	0.46
II-9	K.C., wt., 3	0.87	2	4	0.49
II-9	K.C., wt., 6	0.11	2	4	0.90
II-9	K.C., wt., 9	5.86	2	4	0.06
II-9	K.C., ht., Irr.	1.35	2	4	0.36
II-9	K.C., wt., Irr.	77.32	2	4	0.00
II-10	Honeylocust, 10%	1.66	3	10	0.24
II-10	Honeylocust, 50%	1.32	3	10	0.32
II-10	Honeylocust, wt.	1.00	3	10	0.43
II-10	Kentucky coffeetree 10%	0.79	2	9	0.48
II-10	K.C., 50%	0.97	2	9	0.42
II-10	K.C., wt.	0.79	2	4	0.51
III-1	Trt. Main Effects	15.84	2	27	0.00
III-1	Time Main Effects	20.75	2	27	0.00
III-1	Interaction	1.22	4	27	0.33
III-2	Trt. Main Effects Water Pot.	1.93	2	27	0.17
III-2	Time Main Effects Water Pot.	8.16	2	27	0.00
III-2	Interaction	1.37	4	27	0.27
III-2	Trt. Main Effects Stom. Res.	0.11	2	27	0.89
III-2	Time Main Effects Stom. Res.	16.69	2	27	0.00
III-2	Interaction	1.60	4	27	0.20
III-3	Trt. Main Effects Water Pot.	0.14	2	27	0.87
III-3	Time Main Effects Water Pot.	5.83	2	27	0.01
III-3	Interaction	0.13	4	27	0.97
III-3	Trt. Main Effects Stom. Res.	0.51	2	27	0.61
III-3	Time Main Effects Stom. Res.	7.12	2	27	0.00
III-3	Interaction	1.48	4	27	0.24

Table	Treatment	F	Treatment df	Error df	p
III-5	Trt. Main Effects Water Pot.	0.85	2	54	0.43
III-5	Time Main Effects Water Pot.	6.93	5	54	0.00
III-5	Interaction	0.93	10	54	0.51
III-5	Trt. Main Effects Stom. Res.	2.44	2	45	0.10
III-5	Time Main Effects Stom. Res.	1.17	4	45	0.34
III-5	Interaction	0.24	8	45	0.98
IV-1	Herb. Main Effects Survival	1.90	1	14	0.19
IV-1	Gel Main Effects Survival	0.32	3	14	0.81
IV-1	Interaction Survival	2.21	3	14	0.13
IV-1	Herb. Main Effects Height	2.10	1	14	0.17
IV-1	Gel Main Effects Height	3.61	3	14	0.00
IV-1	Interaction Height	1.56	3	14	0.24
IV-2	Herb. Main Effects	96.77	1	14	0.00
IV-2	Gel Main Effects	2.99	3	14	0.07
IV-2	Interaction	2.09	3	14	0.15

EFFECT OF HYDROPHILIC GELS ON SEED GERMINATION AND PLANT ESTABLISHMENT

by

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Greenhouse and field studies were conducted to determine the effects of hydrophilic gels applied as a seed coating on germination rate and seedling growth. Seeds of several vegetable and tree species were coated with various rates of hydrophilic gel. In the greenhouse, vegetable seeds were planted in Jiffy Mix or sand and tree seeds were tested in sand under various irrigation intervals. In the field, seeds of the various tree species were planted and allowed to germinate with no supplemental irrigation. No significant differences in germination rate or seedling vigor were found among the hydrophilic gel treatments in any species. Tree species did, however respond to more frequent irrigations with faster germination and better growth.

Studies were conducted to determine the effect of hydrophilic gels as transplant aids. In the greenhouse, tomato plant roots were dipped in water or 7.4 g/1 hydrophilic gel solution and placed in sand and a sand and very fine sandy loam mix (1:1 by volume). Plants were also planted in the same media amended with 3 kg/m^3 hydrophilic gel. Leaf water potentials and stomatal resistances were determined. Hydrophilic gel amended media increased leaf water potentials of new transplants in sand, but no effect was apparent as either a root dip or medium amendment in finer textured soil. There were also no treatment effects on plants established for two weeks prior to withholding water.

In the field, maples were exposed to the treatments previously described for tomatoes in the greenhouse study. No significant differences were apparent in leaf water potential, stomatal resistance or visual evaluations among the various treatments.

Experimental procedures were also conducted to determine whether ammonium, nitrate or herbicides are retained by hydrophilic gels. In ammonium and nitrate retention studies, silica sand was amended with hydrophilic gel at the rates of 0, 2, 3 and 4 kg/m^3. One series of concentrations was saturated and another was dry prior to application of ammonium nitrate. The media was washed with distilled water several times, and the leachate was tested for ammonium and nitrate content after each wash. More ammonium was retained in all concentrations of hydrophilic gel amended sand than in sand alone, especially in media not saturated prior to ammonium nitrate application. Nitrate was not retained in large amounts by any media.

Herbicide studies were conducted by amending silica sand as before, then applying simazine or napropamide to a series of gel concentrations. All media was leached with distilled water after herbicide application. Pregerminated oat seeds were utilized in a shoot bioassay to determine whether the herbicides were retained in the various media. Simazine was not retained by any media in large enough quantities to significantly effect survival or growth in any media. Napropamide, however, was retained by all media regardless of presence or absence of hydrophilic gel.