PN-AAF-318

THE POTENTIAL OF STARCH GRAFT POLYMERS, "SUPER SLURPERS," FOR FORESTRY AND AGRICULTURE

TECHNICAL SERIES #2
April 20, 1984
COMPILED BY: _____

Agency for International
Development
Washington, D.C. 20523

THIS COMPILATION IN NO WAY ENDORSES ANY OF THE COMPANIES NOR PRODUCTS CONTAINED WITHIN.

INFORMATION MEMORANDUM

SUBJECT: The Potential of Starch Graft Polymers, "Super Slurpers," for Forestry and Agriculture

"Super slurpers," also called "superabsorbents," (chemically identified as hydrolyzed starch polyacrylonitrile graft copolymers) can absorb 2,000 times their weight in distilled water. Absorbents, thickening agents, soil additives and seed coatings are among their various uses (Sec. I).

Among several uses in forestry and agriculture in the LDC's, I see a great potential for employing superabsorbents to saturate the roots of seedlings before transplanting them in areas that have limited or sporadic rainfall. This would create a reservoir of moisture that the seedlings could draw upon during the critical establishment period. Successful establishment and good early growth of outplanted seedlings are important elements in any reforestation and agricultural program. In an article in the Australian Forest Grower (March 1983), a similar product, Agrosoke, is attributed with having "great potential for establishing trees on difficult sites during the dry season (Sec. II).

In a test conducted in Louisiana for tree seedlings outplanted within 48 hours, survival of seedlings dipped in superabsorbents had an 84% rate of survival, while those dipped in clay slurry had a 49% rate of survival (Sec. IV). In experiments at Auburn University, superabsorbents added to pine

bark medium reduced water stress and increased nutrient retention (Sec. V). At the University of Georgia, superabsorbents increased germination of Phaseolus volgaris "toporop bushbean," increased the water-holding capacity and reduced watering requirements when grown in a soilless growing medium [Metro-Mix 300] (Sec. VI). Results from tests conducted by the Department of Agriculture show that superabsorbents can be used as an inoculant carrier for Mycorrhizal fungi. Treating seedlings with the fungi results in improved growth because root structure is changed, improving the ability of trees to obtain nutrients [(Sec. VII) also see Sec. VIII].

Superabsorbents are reported to improve germination of seeds and increase survival of plants, reduce transplant shock, increase yield, promote faster growth, minimize erosion (by more rapid establishment of ground cover) and permit more efficient use of water resources. It is also said to improve aeration and drainage, and does not promote root rot. Dipping "bare rooted" seedlings keeps the roots moist, increasing survival and minimizing transplant shock (Sec. III).

Often, a growing medium used in containerized nurseries, especially those with high organic content, dries out rapidly after seedlings are removed from the containers and transported over long distances. This results in high mortality. The root mass can be dipped in a superabsorbent slurry, which would act as a binder for the medium and keep the roots moist during transport. Superabsorbent slurries should also be an excellent carrier for Rhizobium and frankia and should be an excellent means of inoculating nitrogen-fixing trees.

V

A modified superabsorbent containing graphite has been developed specifically to coat seeds and to lubricate planting equipment. Absorbent particles draw moisture from the humid air and the soil. In expanding they form a gel "fuzz" at the seed surface. Moisture held by the gel softens seed tissues, promoting rapid germination. Plants grow faster because moisture is readily available to the seedlings (Sec. III).

Another method of direct seeding worthy of consideration is to dig a hole or make one with an auger, then fill it with a good nursery-mix soil combined with a superabsorbent and direct seed into the hole just before the main rainy season. The seeds should be scarified (and dried after scarification) and inoculated with Rhizobium if so required. It is recommended that two or three seeds be placed in each hole and the weaker seedlings that emerge should be weeded out 1-2 months after emergence.

There has been some speculation that superabsorbents might draw moisture from a seed or away from roots in water-stressed soils. Not so, says USDA expert Dr. William M. Doane*: "Under such stressed conditions, the seed or root system would be so dry that it would be dead anyway." The retention forces of the plant are stronger than the suction forces of the superabsorbents. But the suction of the superabsorbents is stronger than the retention of the soil; therefore, moisture would be extracted from the surrounding soil. Dr. Doane and his colleagues at USDA invented this family of chemicals in the 1970's and USDA holds the basic patent on them (Sec. I).

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* Dr. William M. Doane, USDA Agricultural Research, North Central Region, 2000 W. Pioneer Parkway, Peoria, Illinois, 61615, Tel: (309) 685-4011.

Several companies now manufacture and/or distribute variations of the USDA-developed super slurper and some are making noteworthy claims. Henkel Corporation, Industrial Services International, Inc., Spenco Medical Corporation, Grain Processing Corporation and A.E. Stanley Manufacturing Company have advised that they can provide development quantities of starch-based absorbents (Sec. I).

It should be noted that only superabsorbents that have proven effective and beneficial in use with plants should be considered for use in agriculture and related industries. Superabsorbents are available which, if used, could adversely affect plants, as they contain chemicals that may be phytotoxic, or they may hold water with such tenacity that it is not available to plants.

Industrial Services International, Inc. provided information concerning its product, "TERRA-SORB," for use in forestry and agriculture. I have included its information in this compilation along with the more general information on superabsorbents (Sec. III) (Sec. I). ISI states that TERRA-SORB will increase crop production, reduce losses, conserve water, reduce labor costs and in other ways benefit farmers, foresters, greenhouse operators, conservationists and others concerned with the growing of plants (Sec. III).

According to ISI, experiments conducted in a semi-arid area of the United States showed 12-15 % increase in wheat yields in fields using TERRA-SORB compared to those not using it. Tests conducted with oats, beans and other crops have shown that the use of TERRA-SORB as a seed coating can result in a 10-15 % increase in their crop value per acre. Average yield increases of 5-7 bushels per acre have been reported. As reported by the Soil Conservation Service, use of TERRA-SORB 200G doubled the plant growth (height) and accelerated seed production (Sec. III).

ISI gives typical costs for applying TERRA-SORB as: less than $10 to treat a cubic yard of media, which equates to about 6 cents to treat a gallon container, 4 cents to treat an eight-inch hanging basket and 6 cents to treat a 72-cell bedding flat. Used as a gel dip, 50 seedlings can be treated for 1 cent. The cost for use in sodding or hydromulching is 8/10 of a cent per square foot. In transplanting, a plant with a one foot diameter root ball can be treated for 40 cents. The cost for treating 10,000 forestry seedlings is $3.75. One hundred pounds of seed can be treated with TERRA-SORB 200G for approximately $6. Because of the varying quantities of seed planted per acre for various crops, the cost per acre of seed treatment can vary from 10 cents for crops such as tomatoes (1/2 pound of seed per acre) to about $7 for wheat (120 pounds of seed per acre). I assume that the cost of the other companies' products would be approximately the same.

Industrial Services International, Inc., has been kind enough to provide me with a brochure and samples of its product, which I have included as an insert. ISI has also indicated a willingness to provide technical services to demonstrate its product and train people in the use of superabsorbent technology. Those desiring these services are asked to pay for travel and per diem and the company will cover the salary of the technician for a limited time period.

Although I have included ISI's brochures and samples of its products in this compilation, <u>this in no way constitutes an endorsement</u>.

Since the 1970's, superabsorbent technology has evolved to the point where it should be appropriate for use on a commercial scale, especially in areas subject to moisture stress. The practical implementation of this technology

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will do much to increase the efficiency of reforestation and agricultural projects. There will, of course, be a continuing need for additional research to identify additional ways that this technology can be best utalized for the benefit of the LDC's. I would appreciate hearing of the results of the use superabsorbents in the LDC's.

Mike

Michael D. Benge
S&T/FNR Agro-forestation
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Washington, D.C. 20523
April 20, 1984

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f. Weaver, M.O., et. al. 1977. A Practical Process for the Preparation of Super Slurper, a Starch-Based Polymer With a Large Capacity to Absorb Water. Verlag Chemie., pp. 413-422. West Germany.

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m. Pritchard, J.F. and J.J. Quinn. December 1981. Super Soil Moisturizer Challenges Others in Growing Industry. Ornamentals South, pp. 14-17.

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SUPER SLURPER

Compound with a super thirst

A NEW SUPER SLURPER is expected to intensify the interest of industry, agriculture, and science. Besides having a potentially useful "split personality," the new generation slurper can absorb 2,000 times its weight of distilled water.

The new slurper represents the third research generation of a family of water-laboratory starch products discovered at the Northern Regional Research Laboratory, Peoria, Ill.

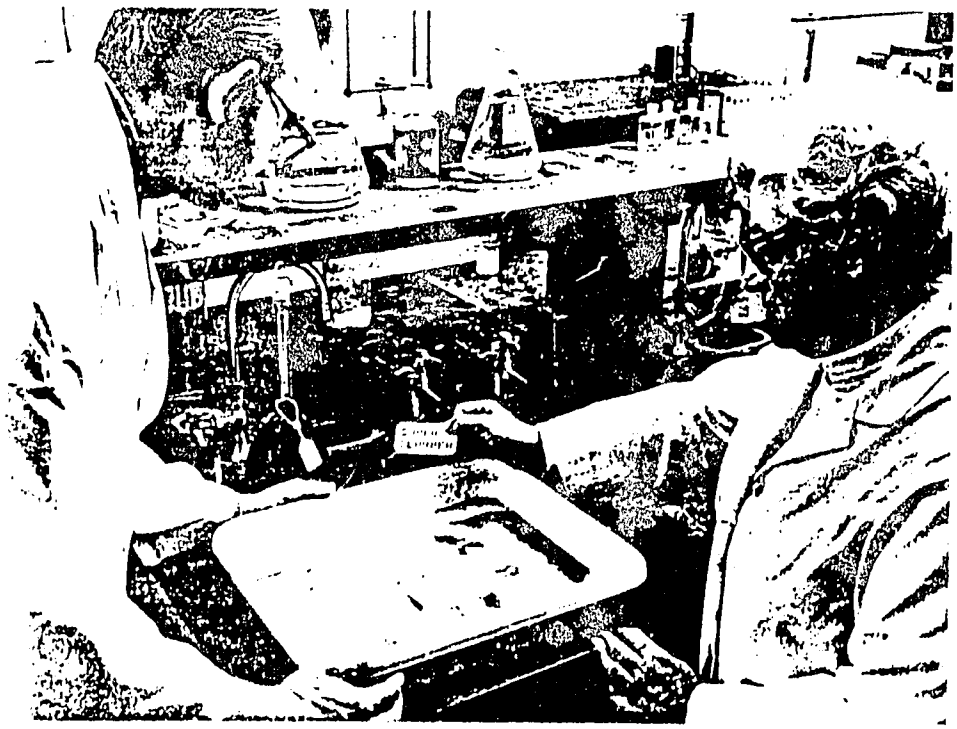
A first generation slurper earned the family name by absorbing 300 times its weight of water. A member of the second generation confirmed the family trait by absorbing 1,400 times its weight of water, half in 30 seconds and most of it in 10 minutes.

Super slurpers, chemically identified as hydrolyzed starch-polyacrylonitrile graft copolymers, are under study by ARS chemists M. Ollidene Weaver, George F. Fanta, Neil W. Taylor, and William M. Doane and engineer Edward B. Bagley, at the Northern Laboratory. With other scientists in ARS, State experiment stations and industry, they are studying slurpers as absorbents, thickening agents, and soil additives.

The researchers are providing information and samples in response to requests from Europe and Japan as well as all parts of the United States. Super slurper has caught the attention of manufacturers of products from disposable diapers and kitty litter to soil conditioners and seed coatings. More than 50 potential applications have surfaced in several hundred letters of inquiry that have been received by scientists at the Northern Laboratory.

Dr. Doane demonstrates that only 2 grams of super slurper will absorb 1,000 grams of water. In powder or flake form the absorbant congeals the water to the consistency of crushed ice. Later generations of the super slurpers can absorb up to 2,000 times their weight of distilled water (0375R222-15A).

Left: Dr. Russell, initiator of the starch grafting studies at the Northern Laboratory, holds a beaker of congealed water. He says that super slurpers demonstrate that components of annually renewable farm commodities can be used to extend and conserve limited petroleum resources and that those combinations of natural and synthetic materials can have useful properties that neither parent material alone has (0375R220-25A). Above: Glistening like crushed ice, but more solid at room temperature, a mixture of 998 parts water in 2 parts slurper surprises Miss Weaver by not flowing from a smooth, flat surface (0375R223-29).

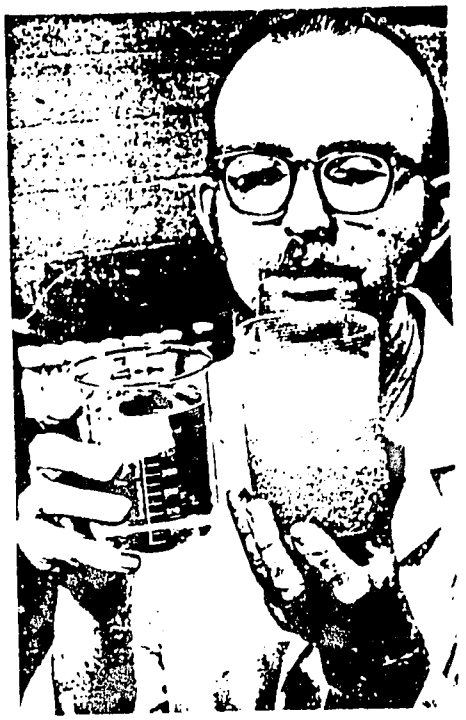


Super slurpers can also be produced in film forms as well as powdered. Dr. Fanta looks on as a film of the compound, originally the size of the stencil held by Miss Weaver, expands three-dimensionally when placed in water (0375R223-8).

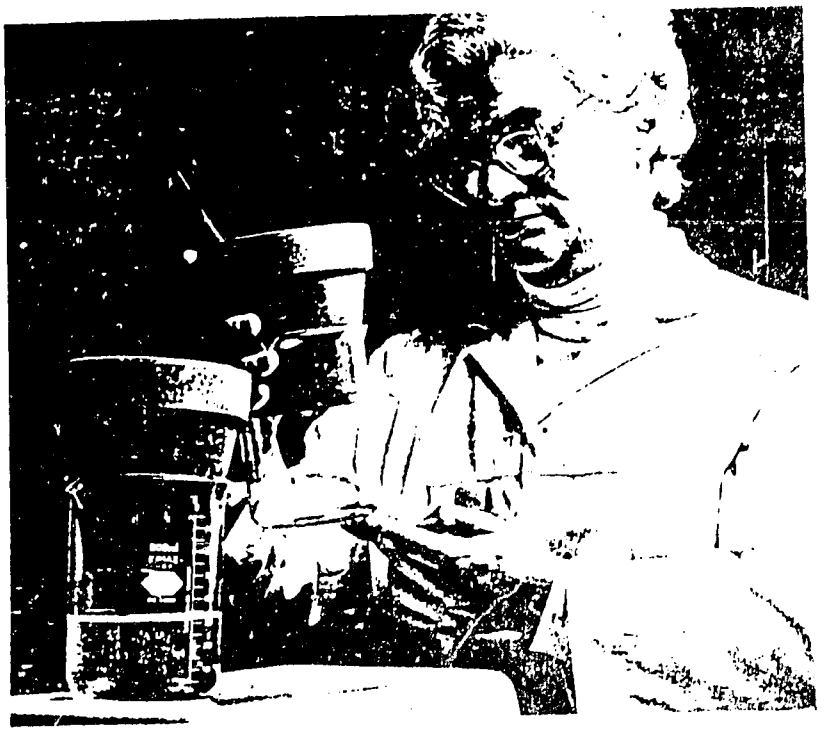
Super slurper III has a "split personality" built in by mechanical treatment. It is a laboratory specimen produced in test tube quantities by Dr. Bagley and Dr. Taylor in basic studies that have been aimed at learning what makes a slurper and how to control it.

Unlike earlier slurpers—which disperse in water to form gels that are difficult to pour—slurper III dissolves, and the solution pours like water. It easily penetrates such porous materials as cloth and sand. When the solution dries and is aged or heated, super slurper III reverts to the family behavior. It forms gel dispersions when water is added again. Slurper III studies show how to make a slurper with a selected capacity of up to 2,000 times its weight of water.

Filling requests for research samples, Miss Weaver and Dr. Fanta regularly make slurpers that absorb 700 to 800 times their weight of water or 55 times their weight of simulated urine. (Simulated urine contains urea, salt, magnesium sulfate and calcium chloride in water.) Against pressure 180 times that caused by gravity, these slurpers have almost 40 times the urine absorption capacity of cellulose fibers.



Dr. Fanta demonstrates that with the help of super slurper a screen wire "beaker" can hold water just as well as a glass beaker (0375R220-36A).



Miss Weaver does an experiment to show one of the potential uses of super slurpers—increase water retention of soils. Sand in the pot on the left held only 50 of 400 grams of water poured through it, while a 500 to 1 mixture of sand and super slurper in the other pot held all 400 grams of water (0375R221-26A).

Cellulose is the main absorbent used in disposable diapers, bed pads, bandages, and surgical sponges. Shortages and rising costs of cellulose are increasing the demand for absorbents that cost less, absorb more, and have less bulk. Bulky materials cause problems in sewage disposal.

What about costs? Estimating the cost of corn starch at 8 cents a pound, engineer Virgil E. Sohns estimates that super slurper could be made for less than 30 cents a pound in a plant with a capacity of 5 million pounds a year.

Dry super slurper can be made as films; thin, cushiony mats; flakes; or powder. When a film takes up water, it expands to a sheet of gel but retains its dry shape. Films of the original slurper, taking up 300 times their weight of water, expanded 33 times in surface area.

Gel sheets contract and become rubbery in dilute acid. They expand again in dilute alkali solution.

Coatings with these properties can be formed on sand grains, straw, wood shavings, all kinds of natural and synthetic fibers, seeds, and other materials where water-absorbent properties would have value. Super slurper can be added in different proportions for different effects to a variety of porous materials like cloth or soil.

Only 1 percent of the slurper (dried in sand) is needed to bind sand firmly enough to be used for molds in metal castings, Dr. Bagley says. As little as 0.1 percent would hold sandy soil surfaces against wind erosion. In either situation, slurper and sand woud absorb and hold more water than sand alone.

Super slurper increased water-holding capacity of sand and greatly enhanced the top growth of oats planted in it in greenhouse tests at Iowa State University, Ames. William D. Shrader, professor of soil management, compared the growth of oats in sand and in a mixture of 1 part slurper to 250 parts sand. He saturated and then drained both the sand and the mixture just before he seeded the oats.

The sand retained only 24 grams of water compared with 317 grams of water held by the sand-slurper mixture. Oats in the sand died 14 days after seeding. The top growth weighed 0.03 gram. By contrast, oats in the slurper-treated sand lived 11 days longer, dying 25 days after seeding. The top growth weighed 0.32 gram.

Dr. Shrader is among more than 700 scientists in agriculture and other industries who have obtained research samples of super slurper from the Northern Laboratory. Other scientists are obtaining samples from General Mills Chemicals, Inc., Minneapolis. General Mills, one of five companies that have licensed a super slurper patent application (Serial No. 456,911), is the only supplier of developmental quantities of the absorbent.

Super slurpers are a branch of the family of starch graft copolymers on which Charles R. Russell, now chief of cereal products research, started research at the Northern Laboratory early in the 1960's. Grafts of acrylonitrile to starch were studied extensively by Dr. Russell, chemists Lewis A. Gugliemeli and Robert C. Burr, and Carl E. Rist, now retired, and others. □

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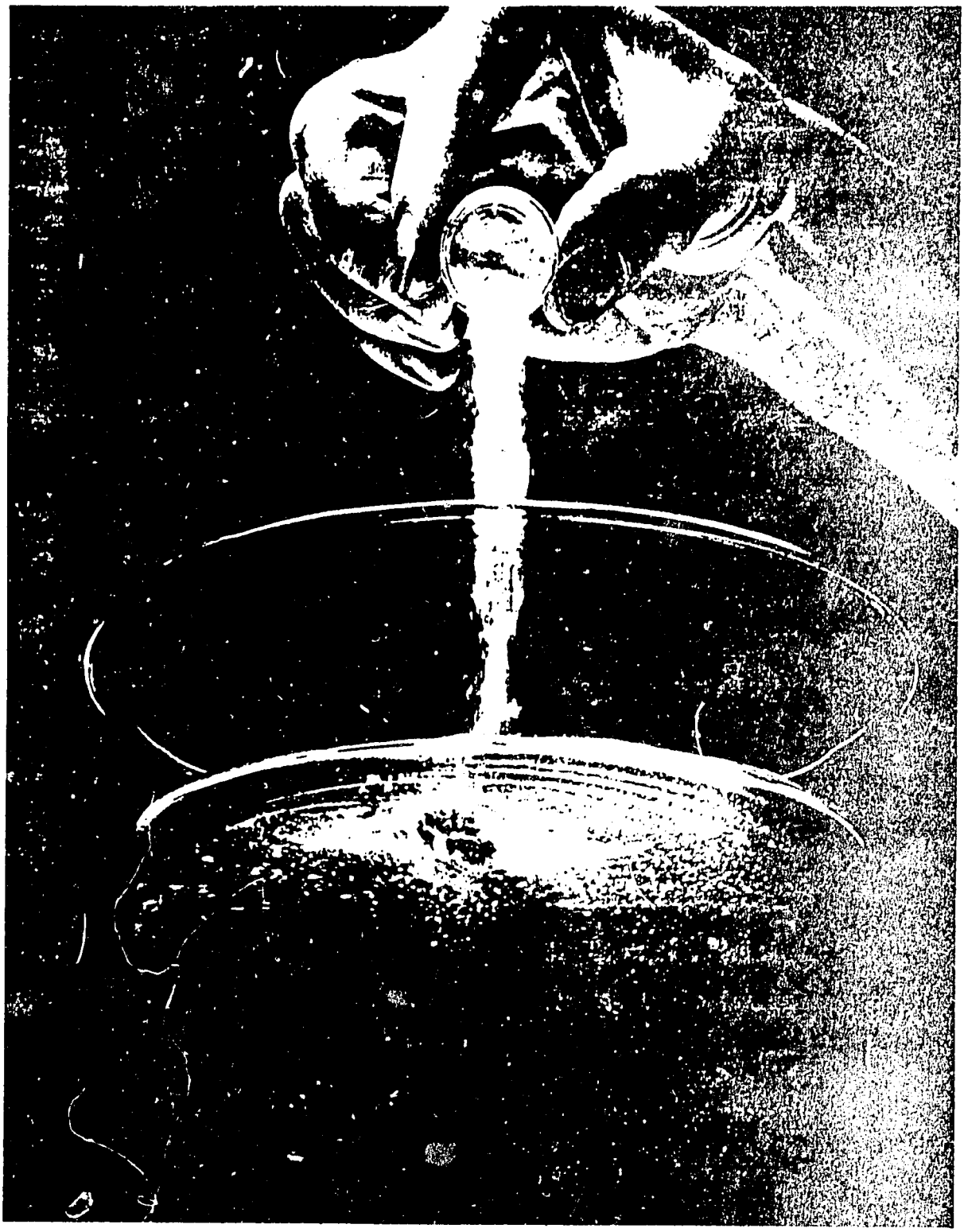

GPO 810-147

POTENTIAL "SUPER SLURPER" APPLICATIONS

Medical (absorption of body fluids--blood, urine, saliva, and prespiration)

- catamenials
- disposable diapers
- bandages
- incontinent pads
- surgical gowns
- surgical sponges
- bed pads
- foot cushions and pads
- gloves (welding, etc., heavy asbestos)
- cosmetics, lotions
- tablet disintegrant
- powders--hand, body
- dental rolls

Agricultural--Horticultural

- seed coatings
- root coatings
- soil additive
- hydroseeding
- seed pelletizing
- pesticide formulations (retain water to improve efficacy)
- drip irrigation (place in irrigation water to deliver gel or swollen particle to soil)
- cut flowers
- retain moisture during shipping of flower and vegetable plants
- agricultural sprays--dispersing or suspending agent
- animal bedding and pet litter

Thickening-Dispersing-Solidifying Agent

- firefighting fluids
- textile print pastes
- radioactive wastes (solidification)
- sludge (solidification)
- athletic fields (remove excess water)
- construction sites (remove excess water)
- basements (remove excess water)
- household products (waxes, polish, paints)

-- over

Thickening-Dispersing-Solidifying Agents--continued

agar substitute (microorganism cultures, insect-growing media, tissue culture)
organic-water systems (must make amine salt rather than sodium or potassium; use thickening paint strippers)
drilling muds and other petroleum applications

Water Removal from Other Liquids

water-oil emulsions
solvents
oil

Binder

foundry core binder (green strength)
pelletizing iron ore
charcoal briquettes

Paper and Textiles

absorbent paper towels and tissues
moisture retention in synthetic textiles as antistatic agent
water retention aid in hardboard manufacture

Concentrate Proteins and Other Polymers

remove water from polymeric materials

Toys and Novelties

Foods and Feeds

(many applications, but require FDA approval in this country)

ABSORBENT POLYMER FACT SHEET

Henkel Corporation, 4620 West 77th Street, Minneapolis, MN 55435; Super Absorbent Company, Route 3, P.O. Box 342, Lumberton, NC 28353 (Distributor: Industrial Services International, Inc., P.O. Box 10834, Bradenton, FL 33507); Spenco Medical Corporation, 6301 Imperial Drive, Waco, TX 76710; Grain Processing Corporation, 1600 Oregon Street, Muscatine, IA 52761; A.E. Staley Manufacturing Company, 2200 Eldorado Street, Decatur, IL 62525 (Attention: D. L. Johnson); and Edison Hydrocontrol Chemicals, Inc., 99 Madison Avenue, New York, NY 10016 have advised that they can provide developmental quantities of starch-based absorbents. The first four listed companies have commercial production capacity.

Four U.S. patents have been issued based on the starch technology (U.S. Patent Nos. 3,935,099; 3,981,100; 3,985,616; 3,997,484). Copies of patents may be purchased (50¢ each) from the Commissioner of Patents and Trademarks, U.S. Patent and Trademark Office, Washington, DC 20231. Non-exclusive, royalty-free licenses are available through Mr. Wayne Thrush, Chief, Program Agreements and Patents Management Branch, U.S. Department of Agriculture, Administrative Services Division, S&E, Federal Building, Room 525, 6505 Belcrest Road, Hyattsville, MD 20782.

A patent (U.S. No. 4,134,863) has issued pertaining to the use of other monomers in conjunction with acrylonitrile. We have been granted a patent (U.S. No. 4,045,387) covering our research on a flour-based absorbent. Developmental quantities of this material are available from Illinois Cereal Mills, Inc., Paris, IL 69144.

(MENTION OF COMPANIES OR PRODUCTS BY NAME DOES NOT IMPLY THEIR ENDORSEMENT BY THE U.S. DEPARTMENT OF AGRICULTURE OVER OTHERS NOT CITED.)

COMMERCIAL PRODUCERS OF SUPER SLURPER

Henkel Corporation
4620 West 77th Street
Minneapolis, MN 55435

Super Absorbent Company
Route 3
P.O. Box 342
Lumberton, NC 28353
(Distributor: Industrial Services
International, Inc.
P.O. Box 10834
Bradenton, FL 33507

Spenco Medical Corporation
6301 Imperial Drive
Waco, TX 76710

Grain Processing Corporation
1600 Oregon Street
Muscatine, IA 52761

(MENTION OF COMPANIES OR PRODUCTS BY NAME DOES IMPLY THEIR ENDORSEMENT BY THE U.S. DEPARTMENT OF AGRICULTURE OVER OTHERS NOT CITED.)

RESEARCH NEWS

SCIENCE AND EDUCATION ADMINISTRATION
UNITED STATES DEPARTMENT OF AGRICULTURE

Doane (309) 685-4011, Ext. 322
Mayberry (309) 671-7158

-Editors: This release is based on research and development reports from 16 sources in 13 states in addition to the Northern Regional Research Center. Names, addresses and telephone numbers of the sources follow the reports.

Additional information on super slurper basic research, 1973 through 1977, and on the Northern Center scientists is available from the address at the bottom of this page.

For release October 22

SUPER SLURPER SWELLS "OUT ALL OVER" IN CROP, CONSERVATION PLANTINGS:

PEORIA, Ill. -- Super slurper, the absorbent that swells as it jells hundreds of times its weight of water, is "swelling out all over" in seed and root coatings, replanting disturbed land, human care products, proprietary developments and increasing production.

Three companies producing the starch-based absorbent report capacities that add up to more than 4 million pounds a year, about double the total claimed capacity a year ago. Other companies, including one with a new super absorbent, are entering the industry that is based on the 1973 discovery in starch research at the Northern Regional Research Center here.

Reports received at the U.S. Department of Agriculture laboratory from industrial and research sources indicate that production will have to continue increasing to keep pace with use and company expectations based on proprietary developments and research results.

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NC-226
10-15-79

Agricultural Research, North Central Region
2000 W. Pioneer Parkway, Peoria, Illinois 61615

Planting uses alone could eventually account for more than 100 million pounds a year of an absorbent that jells hundreds of times its weight of water, estimates William M. Doane, Northern Center research leader.

"Earlier reports pointed toward absorbent soft goods as the most promising application," says Doane, "but planting uses emerged as the leader this year." Research sources report corn, soybean and milo sorghum yield increases ranging from 10 to 50 percent in seed coating field tests. Fifty cents' worth of super slurper returned 50 dollars' worth of increased cotton yield in one test.

A 20-million-tree-a-year nursery reports using super slurper to reduce losses in bare root stock, Doane says. A company using the absorbent in a preparation for "hydromulching" grass seed on disturbed land estimates that up to 10 million acres is disturbed annually as mine spoil, under power lines, over pipe lines, along highways, in airport and dam construction and similar projects.

Some reports list forest fire-fighting aids, incontinent pads and ostomy bags among current non-agricultural applications and refer to what Doane terms "less obvious future applications." These applications range from uses not yet imagined to the practical technology of now.

One producer, for example, refers to potential uses "beyond anything considered at this time." A spokesman for another company believes "the scope and frequently esoteric nature of potential applications" preclude comprehensive development of all uses by one company.

Another company spokesman refers to coming "new applications with patent coverage" and products "to be introduced worldwide." A fourth company, meanwhile, shares hard-learned technology to help develop markets

- more -

NC-226
10-15-79

"The reports reflect the early stages of an industry based on a new concept," Doane says.

Several water-jelling absorbents, made by chemically grafting man-made acrylic compounds to cereal grain starch and hydrolyzing the combinations, were introduced as super slurpers, 1973-77, by Doane, M. Ollidene Weaver, George F Fanta, Edward B. Bagley and other scientists at the Northern Center.

The super slurpers, absorbing 300 to 5,300 times their own weight of pure water in the laboratory, established new standards of absorbency and a name for the standards, the products and the industry. Henkel Corporation, formerly General Mills Chemicals, Minneapolis, is taking steps to trademark "Super Slurper."

Three companies produce the starch-based absorbent. Henkel licensed the first USDA patent application in August 1974; Super Absorbent Company, Lumberton, N.C., in March 1976, and Spenco Medical Corporation, Waco, Tex., in October 1977. A total of 45 companies or individuals have licences on three USDA patents now.

A. E. Staley Manufacturing Company, Decatur, Ill., is announcing a new absorbent in the super slurper class. American Ag & Bio-Tech, Inc., North Little Rock, Ark., plans to produce seed coatings. Bioferm International, Moorestown, N.J., is marketing agricultural products containing a super slurper and expects to produce its own absorbent within 2 years.

Howard E. Worne, president, Bioferm International
209 Chester Ave., Moorestown, N.J. 08057
Ph. 609/234-2884

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Henkel announced in June 1978 a 2 million pound-a-year plant at Kankakee, Ill., to develop markets. That capacity has doubled reports Earl Skinner of the SGP Polymer project. "We expect to be the dominant super absorbent supplier," Skinner says and adds that the company is expanding also in marketing and research, especially in developing technology.

Henkel has developed and released information on using SGP in seed coatings and soil additives, "soil-less" potting mixes and electrostatic coatings on tissue and other paper-like materials for diapers and pads. Skinner says releasing the information helps develop markets.

"We are expanding service in personal care and several emerging industries with high quality material and a variety of new products," says John Gilmore, also on the SGP project.

"We have extensive seed coating technology," Gilmore says. "It permits adding thin coatings, which do not change seed size substantially, or pelletizing which does increase seed dimensions significantly

"We can coat seeds as small as guayule, as large as castor beans and as frail as peanuts." Guayule is a rubber-producing desert plant under development as a United States rubber crop.

Gilmore says seed coating research is continuing on vegetables and other crops including corn, sorghum, soybeans, sugar beets, guar and jojoba, a desert shrub that produces a liquid wax replacement for sperm whale oil.

Super slurper coatings "form a gel capsule of water around each seed," Gilmore says. "The amount of coating is extremely important in providing water uptake without drowning the seed.

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"The coatings lead to an increase in stand from lower seeding rates, better emergence, more uniform and vigorous stands and higher yields." He says the coatings help especially in dry land planting, under irrigation, on low quality seed, and in double cropping, for example, soybeans in wheat.

He says other materials can be added to super slurper seed coverings to protect against disease and insects, break down seed coat impermeability, absorb toxic residues of herbicides and stimulate root growth or the germinating embryo. A test covering on cottonseed, for example, contained fungicide and embryo stimulant.

Cottonseed coated with super slurper produced 50 dollars' worth more cotton an acre than uncoated seed produced last year in a test near Vernon, Tex. Applied at the rate of a pound to 100 pounds of seed, the absorbent cost about 50 cents an acre.

John Gilmore, SGP Polymer Project, Henkel Corporation
4620 West 77th St., Minneapolis, Minn. 55435
Ph. 612/830-7891

Slurper-coated corn "planted under moderate to severe moisture stress" produced 4,100 more plants an acre than "naked seed" produced and yielded 13 more bushels than the 123-bushel control yield in field tests by Dale E. Behmer of American Ag & Bio-Tech.

Behmer says coated soybeans broadcast in chemically killed sod "showed 7 to 28 percent stand improvements" over uncoated beans in Arkansas tests. Highest yield increase from coating soybeans was 18 bushels an acre.

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Coating milo seed increased yields in a range of 17 to 49 percent on chemically killed sod in Behmer's Arkansas tests.

Dale E. Behmer, president
American Ag & Bio-Tech, Inc.
P.O. Box 9147
North Little Rock, Ark. 72119
Ph. 501/227-6107

At least one step beyond planting coated seed is the possibility of sowing pregerminated seed in a super slurper gel. "The gel protects the exposed root from damage and facilitates planting," says Alan Taylor, research assistant to James Motes in the Oklahoma State University Department of Horticulture.

Taylor says the gel-seeding technique offers "earlier emergence, better and more uniform stand and greater ability to withstand environmental stresses. It can be used on flower, tree or crop seed as well as on vegetable seed.'

He says that 20 acres were planted with pregerminated vegetable seed this year. "Greenhouse growers will benefit in the future by sowing pregerminated seed," Taylor says.

"The significance to consumers may not be seen for several years. The question is will the technique be accepted by the vegetable industry and to what extent."

Alan Taylor, research assistant
c/o James Motes
Department of Horticulture
360 Agricultural Hall
Oklahoma State University
Stillwater, Oklahoma 74074
Ph. 405/624-5404

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Florida nurserymen and other growers use super slurper to start and grow high value vegetables, foliage plants and ornamentals in trays, beds, pots and sandy fields where water is vital and expensive.

James J. Quinn, Industrial Services International vice president for agriculture, says the absorbent cuts water use 90 percent on bedding plants and seed trays, cuts misting time on foliage plants and shortens the usual 4 to 5 weeks between potting plants and marketing them by about a week because the plants develop faster in slurper-treated soil.

Quinn says farmers, greenhouse operators, nurserymen, condominium owners, landscapers and bare-root shippers use the absorbent in areas ranging from mini trays to acreages for all kinds of plant growing. "The only exception is hydroponics," he says.

One seed germinating company turns out a million vegetable and ornamental seedlings, 595 per 2-square foot tray, an hour for sale to commercial growers. A palm tree grower expects to cut his 100 dollar/acre/year water bill. Sod layers broadcast a pound of the absorbent to 500 square feet before they lay sod on sandy soil. Quinn says super slurper holds water in the root zone instead of allowing it to soak deeper into the sand.

He says his "tongue is hanging out from keeping up with the marketing," and he wonders whether super slurper producers can keep up with the use.

James J. Quinn, vice president for agriculture
Industrial Services International
5309 36th Avenue Drive West
Bradenton, Fla. 33505
Ph. 813/792-7778

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For mulching seed on disturbed land, called "hydromulching" because the mulch is applied in water, Grass Growers, Plainfield, N.J., uses super slurper as a binder or tackifier as well as absorbent. Charles DeAngelis says he was "looking for materials not on the endangered species list" (replacements for petrochemicals) when he heard Burgess Kay of the University of California, Davis, report research on the starch-based absorbent.

DeAngelis says super slurper and fibrous mulching materials in water develop into a viscous slurry not toxic to plants or other living things. The absorbent dries to a water-absorbing, insoluble film that holds hay, straw or wood or paper fiber together. This forms a kind of thatch that protects seed and soil against heavy rains but absorbs moisture to help seeds grow, DeAngelis says.

He claims Grass Growers' Terra Tack AR is a "replacement for an endangered species," asphalt.

Charles DeAngelis
Grass Growers, Inc.
424 Cottage Place
Plainfield, N.J. 07060
Ph. 201/755-0923

Musser Forests, Indiana, Pa., uses and markets super slurper as Water Gel for root coatings. "We think this is just the product we have been looking for to reduce losses in bare root trees," reports Fred Musser, Jr.

He estimates that Musser Forests coated the roots of 2.5 million trees for shipping in 1979. Large orders are not root coated now because water held on the roots adds to the transportation cost.

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"We feel that super slurper will retain moisture around roots of plants during shipment better than other materials we have tried," Musser says. "It also appears to increase the survival rate of bare root plants for field planting in hot, dry weather."

This year's experience gave an example, Musser says. The nursery completed its own plantings late -- in the hot, dry weather of June. By the middle of September, 85 to 90 percent of the root-coated seedlings were growing. Survival rate of untreated seedlings was zero.

Fred Musser, Jr.
Musser Forests, Inc.
Indiana, Pa. 15701
Ph. 412/465-5686

Coating roots and seeds and hydromulching might be considered "localized soil treatments," efforts to increase water retention of the soil in close proximity to plant roots. Soil treatment of a more general scale has been studied.

David E. Miller, USDA soils research leader at Prosser, Wash., studied effect of super slurper on water retained by soils after irrigation. "Although present costs of super slurper may be prohibitive, except for specialized conditions and high value crops," Miller says, "our data indicate that water retention of sandy soils can be greatly increased by treatment with super slurper." Some sandy soils are "marginally irrigable because of low water retention," he says.

He added super slurper at the rate of 0.5 percent by weight to the upper 60 centimeters (about 2 feet) of sand in laboratory soil columns. This treatment "increased the available water retained by the sand to nearly the same levels as that

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retained by a loam and a silt loam," Miller says. "This effect could also decrease wind erosion through maintaining a moist surface for a longer period after irrigation.

David E. Miller, research leader
Irrigated Agriculture Research and Extension Center
Science and Education Administration, USDA
P.O. Box 30
Prosser, Wash. 99350
Ph. 509/786-3454

Based on Iowa field and laboratory tests starting in 1975, W. D. Shrader, Iowa State University professor of agronomy, says, "A sandy soil treated with 0.2 percent by weight of super slurper has about the same water holding capacity as the best of the Corn Belt soils."

Complete modification of a sandy soil would be "prohibitively expensive," he says, "but there are situations in which slight or localized increases in available soil water would be highly beneficial." He cites, for example, a field trial on a very sandy, 30-percent slope on a dam construction site near Webster City, Iowa. The area was devoid of vegetation.

Alta fescue was seeded in three sloping areas treated with 0.0, 0.1 or 0.2 percent of super slurper. After 3 months, fescue harvested from the 0.2-percent area weighed four times as much as that from the untreated area and twice as much as fescue harvested from the area that received 0.1 percent super slurper.

Prof. W. D. Shrader is retiring from the Department of Agronomy, Iowa State University, and not available to answer questions. The information is based on "Potentials of a Polyacrylonitrile-Starch Polymer, Super Slurper, To Modify Water-Holding Properties of Soils," Journal paper No. J8681, Iowa Agriculture and Home Economics Experiment Station, Ames, as published in Coatings and Plastics Preprints, Vol. 37, No. 1, American Chemical Society, 173rd National Meeting, New Orleans, 1977.

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An Iowa company has added super slurper to the formulas for products applied to seed, soil or plant leaves for horticultural and field crops, mainly soybeans, corn and small grains.

Marie Anderson of In Vivo, Inc., Iowa City, says super slurper improves uniformity of distribution of other components in the products and adds water-holding capacity.

The formulas include sources of nitrogen, phosphorus and potassium, chelated trace elements and proprietary ingredients. Anderson says soil and foliar products are applied as need is indicated by soil or plant tissue tests. Seeds can be treated by either wet or dry processes.

She says farmers as well as flower and ornamental growers are among repeat customers.

Marie G. Anderson, general manager
In Vivo, Inc.
Box 2537
Iowa City, Iowa 52244
Ph. 319/338-5135

Super Absorbent Co., producing about 150,000 pounds of Magic Water Gel a year for tree, tobacco and tomato root coatings and for ostomy bags, has installed equipment for a second slurper product.

Tobacco growers tell Ed Kirkland that in 2 years' experience, root coatings give greater results if soil conditions are dry at planting time. They claim that root coatings give plants a faster start and cut replanting in half.

One grower, Willis Branch, told Kirkland, "At the time of topping, these (treated plants) were 6 to 8 inches higher than the rest."

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Tomato growers say root coatings give "better survival and stronger, bigger, earlier producing plants."

Kirkland says "This material has capabilities for uses beyond anything considered at this time."

Ed Kirkland
Super Absorbent Company
Route 3, Box 342
Lumberton, N.C. 28358
Ph. 919/739-3839

Spenco, with an annual production rate of about 250,000 pounds, markets a super slurper called "Absorption Flakes" for ostomy bags and incontinent pads. We are doing market development work in all areas, including a concerted effort in the medical field," says Research Director Edward Stout. "We are working with other companies to develop other uses.

"New uses being investigated have potential markets of millions of pounds a year." Spenco soon will introduce new products with patent coverage on a world wide basis Stout says.

Ed Stout, director of chemical research
Spenco Medical Corporation
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Waco, Tex. 76710
Ph. 817/772-6000

A new starch-based absorbent, Stasorb 372 is available from A. E. Staley Co. for testing and limited scale evaluation. "Stasorb is functionally similar to super slurper, which served as incentive and model," says H. W. Renshaw, marketing communications manager. "Chemically, however, Stasorb is the potassium salt of a starch polyacrylate graft copolymer and, therefore, exhibits certain properties that differ from those of super slurper."

Potential applications of Stasorb include controlling wind erosion of soils; dust abatement in ore and coal excavations, and use on gravel and dirt roads and race tracks. Additional potential uses include removing water from mixtures, including water-hydrocarbon mixtures; soil conditioning; seed coatings; diapers, feminine personal care and incontinent pads; flocculating and stabilizing agents; moisture proofing underground tanks and cables and in pet and animal litter products.

"We believe the scope and frequently esoteric nature of the potential applications preclude the establishment of all encompassing usage programs by any one company, producer or consumer," Renshaw says. "Each application will most probably require a specific research and development effort."

H. W. Renshaw, marketing communications manager
A. E. Staley Manufacturing Company
2200 Eldorado St.
Decatur, Ill. 62525
Ph. 217/423-4411

Plant tissue culturing and insect feeding are two esoteric applications reported to the Northern Center.

Flow Laboratories, Inglewood, Calif., is distributing super slurper (the potassium salt) as Plantgar for use as a gelling agent in plant tissue culture. In research on Boston ferns, Ron C. Cooke found, "The agar substitute requires no boiling to dissolve and appears to promote more shoot initiation than agar-solidified medium."

Ron C. Cooke, technical staff
Flow Laboratories, Inc.
936 W. Hyde Park Blvd.
Inglewood, Calif. 90302
Ph. 213/674-2700

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USDA Entomologist Norman C. Leppla, Gainesville, Fla., tried super slurper, starch and two cellulose derivatives in cabbage looper diets to retain moisture, bind other ingredients and provide acceptable texture. He says methyl cellulose and super slurper "were the most practical materials and produced the greatest number of adequately sized pupae in the least time."

Norman C. Leppla
Insects Research Laboratory, USDA
Gainesville, Fla. 32604
Ph. 904/373-6701

In Honolulu, another USDA entomologist, Norimitsu Tanaka, used super slurper to control free water in a fruit fly diet. Although he changed the standard diet and no longer uses the absorbent, Tanaka says, "Super slurper eventually will be used in many diets, especially for insects with long larval periods where drying problems are encountered. Currently, we can use super slurper to keep eggs in suspension for seeding onto the diet through a spray nozzle and as a water source for adults."

Norimitsu Tanaka
Subtropical Fruit Insects Research, USDA
P.O. Box 2280
Honolulu, Hawaii 96804
Ph. 808/988-2158

Super slurper and similar absorbents have potential in the floriculture industry reports Richard Gladon of Iowa State University's Department of Horticulture. He is trying super absorbents in rooting and establishing chrysanthemum cuttings.

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Although he has no final results, Gladon says the super absorbents possibly can save water, save work in watering and save fuel used in sterilizing root media. He points out that floriculture is a large and growing industry and the bedding plant segment is the largest.

Richard Gladon
Department of Horticulture
Iowa State University
Ames, Iowa 50011
Ph. 515/294-1916

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A Practical Process for the Preparation of Super Slurper, a Starch-Based Polymer with a Large Capacity to Absorb Water

By M. O. Weaver, R. R. Montgomery, L. D. Miller, V. E. Sohns, G. F. Fanta and W. M. Doane, Peoria, Illinois (USA)

The solid, water-insoluble sorbent called Super Slurper that swells in water is a base hydrolyzed starch-polyacrylonitrile graft copolymer in which the nitrile functionality has been converted to a mixture of carboxamide and alkali metal carboxylate. A process for making the polymer in multipound quantities has been developed from laboratory scale-up studies. This process avoids intermediate isolation steps, permits efficient removal of unreacted monomer, keeps the concentration of extraneous salts low and gives a high solids concentration for the drying step. Variation in drying procedure allows Super Slurper to be made in film, mat, powder or flake form. Shearing the hydrolysis mixture prior to isolation and avoiding extended exposure of isolated product to elevated temperature gives Super Slurper with highest absorptive capacity. All equipment used is common to industrial practice. The cost to make crude drum-dried flakes is estimated preliminarily as $ 0.32/lb for a 10^7 lb/year hypothetical plant.

(Zusammenfassung Seite 421; Résumé à la page 421)

1. Introduction

Recently, absorbent materials with the capacity to imbibe and hold water have been the target of great attention from investigators who hope to solve diverse problems by using such materials. Areas of preliminary testing have included crop production, i.e., seed coating [1, 2] and soil amendment [3] and personal care items [4]. The highly absorbent starch-based polymer developed at our laboratory is formed when a starch-polyacrylonitrile (SPAN) graft copolymer is

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hydrolyzed with aqueous alkali and then dried [5] (see Fig. 1). Variation in drying procedure allows Super Slurper, as the absorbent has been called, to be made in film, flake, powder or mat form.

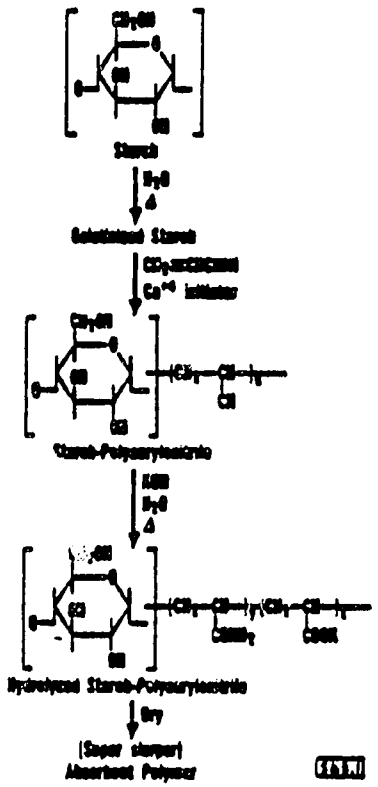

Figure 1. Reaction scheme for preparation of absorbent starch-based polymer called Super Slurper.

Initial observation of unique absorbency of hydrolyzed SPAN (H-SPAN) in the dry salt state was made when a dispersion of H-SPAN was allowed to dry: the resultant film expanded three dimensionally when placed in water, rapidly taking up several hundred times as much water as its own dry weight [6] (see Fig. 2). Super Slurper has many of the properties described by Burkholder [7] as desirable for products which might be incorporated into nonwoven disposables. We therefore first examined the absorbent for this area of application [8] and found that it, being a polyelectrolyte, is affected by ions in the solution absorbed. Super Slurper which absorbs 600–900 g of distilled water per g will absorb 60 g of solution calculated to simulate urine (1.94 % urea, 0.8 % NaCl, 0.11 % $MgSO_4 \cdot 7H_2O$, 0.06 % $CaCl_2$ and 97.09 % H_2O). In contrast, mechanically fluffed cellulose fibers absorb 32 g of simulated urine per g; but when centrifuged at 180×g they hold only 1 g of absorbed liquid per g of cellulose. One gram of Super Slurper will hold 37 g of simulated urine at 180×g. This ability to hold liquid under moderate pressure suggests that Super Slurper has real potential as an absorbent.

Early laboratory procedures for the hydrolysis of SPAN were intended to produce water thickeners, i.e. materials which would disperse in water with the addition of dilute base to give viscous dispersions. Three preparative steps were used: (i) the graft copolymer was formed and then isolated so that unreacted monomer, salts, ungrafted starch

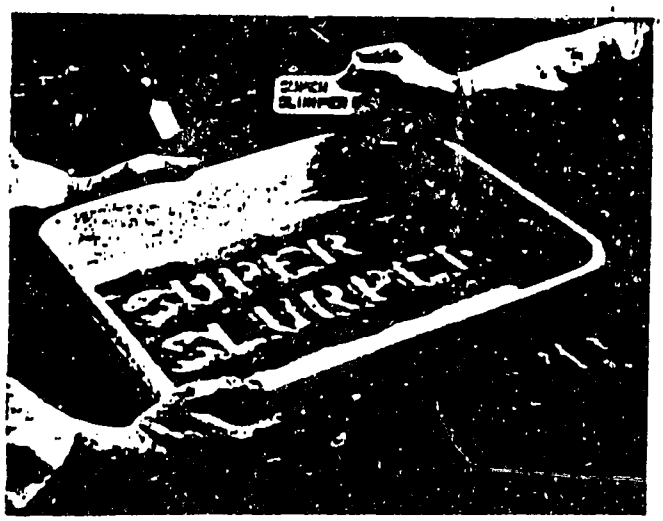

Figure 2. A film of Super Slurper cut to desired shape (see hand-held template) and then immersed in distilled water, swells uniformly in all directions. Note letters visible in swollen film in tray.

and polyacrylonitrile homopolymer could be removed; (ii) the graft copolymer was base-hydrolyzed and the reaction mixture was then acidified to pH 3 to permit isolation and purification of the saponified polymer as the free carboxylic acid; (iii) the saponified polymer was dispersed in water with the addition of dilute base to give a viscous dispersion. Drying of this thick dispersion gave our first absorbent polymer [6, 8].

In this report we will discuss ways to scale-up, improve upon and make more practical our laboratory preparation methods [9, 10]. We consider that a practical procedure for making absorbent starch-based polymer would: (i) avoid intermediate isolation steps, (ii) permit efficient removal of unreacted monomer so that treatment with alkali does not form undesirable monomeric acrylamide, (iii) keep the concentration of extraneous salt low and (iv) give high solids concentration for the drying step. To achieve these goals, it is necessary to select equipment that will confine the highly volatile, toxic monomer for the grafting step and have the capability to mix the very heavy dough generated during alkaline hydrolysis.

2. Experimental

2.1. Materials

Acrylonitrile (99.5 % pure) was obtained from Vistron Corp., Lima, Ohio. MEHQ is present as stabilizer to the extent of 35–45 ppm (wt. basis). Dow Corning antifoam AF emulsion is made by Dow Corning Corp., Midland, Michigan. Ceric ammonium nitrate came from G. Fredrick Smith Chemical Co., Columbus, Ohio. Potassium hydroxide was obtained as 45 % caustic potash from Ashland Chemicals, Columbus, Ohio. Sodium hydroxide was obtained as 50 % caustic soda (reagent grade) from McKesson & Robbins Drug Co., Peoria, Illinois. Starches were supplied by the following: *wheat starch*, MSWS-100, spray dried, Midwest Solvents Corp., Atchison, Kansas; *corn starch*, Globe Industrial Modified, CPC International Inc., Englewood

Cliffs, New Jersey; *starch from waxy maize*, Amioca, National Starch & Chemical Corp., Bridgewater, New Jersey.

2.2. *Equipment*

For our small-scale studies, we used a 1-1/2 ft^3 ribbon blender (J. H. Day Co.). This blender (shell work. press., 30 psi at 292 °F, jacket work. press., 45 psi at 292 °F) is equipped with an external heat exchanger and a thermistor probe connected through a transducer to a recorder, thus permitting continuous monitoring of temperature. The blender also has a pneumatically controlled discharge gate.

Large quantities of polymer were made in a ribbon blender (J. H. Day Co., Model C, 10 ft^3 working capacity, Fig. 3) jacketed to permit steam heating or water cooling (jacket work. press., 50 psi at 298 °F, shell work. press., atmos. at 298 °F). The blender is equipped with a double ribbon type agitator and a center discharge port. The agitator shaft is bored its entire length, and 20 sparge ports 1/8 in. in diameter are equally spaced to permit the introduction of steam into the product during processing. Material of construction is stainless steel, type 316, on all product-contacting parts. Power is supplied to the agitator by a 5-hp motor equipped with a variable speed transmission and chain drive. The blender was fitted with side fill tube, pressure gauge, thermometer, vent valve, overhead heat exchanger for condensing vapors to be collected in a receiver and a valve port to permit sampling and the addition of monomer. The blender was placed under a canopy-type hood.

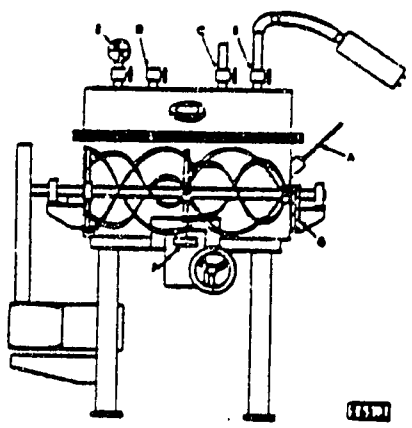

Figure 3. Ten cubic foot ribbon blender. *A* = side fill tube, *B* = valve to heat exchanger, *C* = vent valve, *D* = sample port and monomer addition port, *E* = pressure gauge, *F* = discharge port, *G* = thermometer.

To achieve the high-speed, high-shear mixing necessary to prepare higher absorbency products, we used a 3 ft Hydrapulper (Fig. 4) built by Shartle Bros. Machine Co., Middletown, Ohio. This machine has an 18-in. diameter rotor having 18 outside 7/8-in. vanes and eight inside 11/16-in. vanes; the rotor's peripheral speed is 3780 ft/min. The Hydrapulper is equipped with a solid, stainless-steel bottom plate to replace the usual perforated one.

The drum dryer is Model GF10 made by General Foods Package Equipment Corp., Benton Harbor, Michigan. It has a variable speed motor and is modified for steam heating the drums.

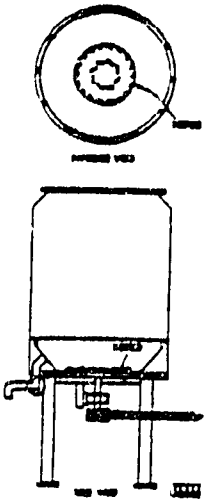

Figure 4. Hydrapulper. Top drawing shows interior view with fixed vanes and vaned rotor.

The Cowles disintegrator was Model 7RT with a 5-hp motor; the disintegrator shaft speed is 3000 rpm.

2.3. *Small Scale Reaction*

Sixty pounds (27.3 kg) of distilled water and 4.74 lb (2.15 kg) of starch (14 % moisture) were charged into the blender, the lid set in place and the starch cooked at 194—200 °F (90—95 °C) for 30 min. The dispersion was cooled to 86 °F (30 °C), the lid was raised and 4.41 lb (2 kg) of acrylonitrile (AN) was added, followed by 2.21 oz (62.6 g) of ceric ammonium nitrate dissolved in 2.5 lb (1.1 kg) of 0.1-N nitric acid. The lid was set in place and the mixture was stirred for 2-1/2 h. The pH of the mixture was then adjusted to 7.5 with 1.1 lb (500 ml) of 1-N potassium hydroxide, and a little antifoam emulsion was added. AN-water azeotrope was distilled for 2 h, after which the mixture was cooled slightly, and 3.8 lb (1.724 kg) of potassium hydroxide pellets was added. Saponification proceeded at 95 °C for 1 h. The reaction mass, typically about 70 lb (31.8 kg), was discharged.

2.4. *Scale-Up Reaction*

Four-hundred pounds of distilled water was charged by gravity flow through the side fill tube (Fig. 3) leading from an upper deck reservoir. After 34—1/4 lb of starch was added to the stirred water and the reactor lid set in place, the reactor was heated by applying 38—40 psi steam to the jacket. The starch dispersion temperature rose to 180—195 °F and was held at this temperature for 30 min, while gelatinization took place, after which the steam was vented from the jacket and cooling water was applied in its place. When the starch dispersion had cooled to a temperature of 90 °F or less, 34.5 lb of acrylonitrile, which had previously been siphoned from its commercial drum into a suitably shielded carboy, was blown into the reactor through port *D* (Fig. 3) using nitrogen at a pressure of 2 to 3 psi. We found this method satisfactory for handling volatile, toxic AN. After all the AN was added, 0.78 lb of ceric ammonium nitrate was dissolved in 14 lb of 0.1-N nitric acid and the solution added through port *A*. The temperature of the reaction mass rose shortly after addition of initiator was completed,

and this exotherm continued at a rate of approximately 1 °F/min for 30 min. When the exotherm was completed (30 min), 70 g (arbitrary amount) of commercial antifoam in 1 lb of water and sufficient commercial 45 % potassium hydroxide to neutralize the acidic reaction mass were added through port *A*. Valve *B* to the heat exchanger was opened and steam was applied to the reactor jacket. After 30 min of heating, AN-water azeotrope began to distill. Distillation was continued for 1–2 h until the distillate was clear. To avoid foam formation and a pressure build-up, for which the equipment was not designed, cooling water was run through the jacket until the internal temperature dropped 30 °F. Fifty pounds of distilled water was added through port *A* to make up for water lost during distillation and then 44.5 lb of commercial potassium hydroxide solution was added for saponification. Steam was applied to the jacket at 38 psig and maintained for 1 h after which the pressure was reduced to 7 psig. Steam was passed through the hollow perforated shaft to purge the reaction mass of byproduct ammonia. Jacket and sparge steam was shut off and cooling water was applied to the jacket. When the reaction mass had cooled to 170 °F, the reactor lid was removed to show a light tan, bread-doughlike material which had a pH of 12.5. Eight pounds of glacial acetic acid, well mixed into the dough, reduced the pH to 8. The dough was removed from the reactor via the discharge port (*F*) and was found to contain 17.8 % solids.

As an alternate method for gelatinizing the starch, we used a Penick & Ford laboratory model continuous cooker [11] with a pumping rate of 0.31 gal per min and a slurry tank capacity of 1 gal. Starch (33-1/4 lb) in a 12 % aqueous slurry was continuously gelatinized with steam at 240 °F, and the dispersion was then diluted to 7 % starch concentration. This dispersion was pumped into the 10 ft³ ribbon blender and cooled to below 90 °F.

2.5. Preparation of Crude Flakes

The wet material from section 2.4 was hand-fed into a center feed, double drum dryer with a drum spacing of 0.002-in. at drying temperature. This dryer has 12×18-in. drums with a total drying surface (both drums) of 9.42 ft². The drums are heated with 55 psig steam and rotate at a speed of 2 rpm. Surface temperature of the drums was 240–250 °F, and the dry product peeled off in sheets at a rate of about 6 lb/h. The drum-dried polymer (5–10 % moisture) was ground through a 3/8 in. roundhole screen in an Abbe mill to give crude flakes which typically absorbed 250 g distilled water or 48 g of 1 % NaCl solution per g. Moisture content varied with relative humidity.

2.6. Preparation of Refined Powder

Fifty pounds of the hydrolysate (17.8 % solids, pH 8, section 2.4.) was placed in a 50-gal baffled, stainless-steel barrel and placed under a sawtooth Cowles disintegrator. At a rate just sufficient to prevent stalling of the stirrer, 14 lb of distilled water and 50 lb of 95 % ethanol were added to the heavy dough; when good dispersion was achieved, the mixer was stopped and the solid was allowed to settle. The supernatant was removed by means of a valved side opening at the bottom of the drum. The solid was washed twice with 50-lb portions of 95 % ethanol and the final granular product was placed in trays and dried in a forced-air oven at ambient temperature. The granular Super Slurper (11 % moisture) was ground in a laboratory hammer mill, using care to avoid appreciable temperature build-up. The ground polymer (34 % held by a 120-mesh screen and 31 % held by a 325-mesh screen) absorbed 600 g of distilled water, 100 g of tap water or 50 g of 1 % NaCl solution per g.

2.7. Preparation of Higher Absorbency Products

Higher absorbency products can be obtained by mechanically shearing the hydrolyzed graft polymer. A Hydrapulper was used for the shearing process and 45 pounds of distilled water filled the voids under the rotor and in the large exit piping. An additional 140 lb of distilled water were metered into the Hydrapulper, and while this was stirring, 50 lb of alkaline hydrolysate (pH 12.5, 20 % solids) from the ribbon blender were added slowly. After the mixture had stirred for 90 min, the temperature reached 140 °F, and considerable additional ammonia evolved. Brookfield viscosity of the mixture (now at pH 10.1 and 5 % solids) was 78,000 cp (6 rpm) at 110 °F. Hydrapulped material was recovered, and 50 lb was neutralized with 52 ml of glacial acetic acid and then drum dried. The crude flakes obtained after coarse grinding absorbed 700 g of distilled water per g. The remainder of the hydrapulped material was precipitated with alcohol as described in section 2.6. A small amount of potassium acetate was added during precipitation to clarify the supernatant. This precipitated product, after drying and grinding through a 1/8-in. round hole screen absorbed about 1300 g of distilled water per g.

2.8. Processes to Make Films and Mats

Refined product (section 2.6.) before drying was dispersed in distilled water at a concentration of 0.5 to 1 % using a Cowles disperser. The resultant clear, viscous dispersion was poured through cheesecloth to remove any remaining lumps and then was poured into plastic-lined trays and dried in a forced-air oven at ambient temperature to give clear films whose flexibility varied greatly with their moisture content.

Two pounds of refined powder (section 2.6.) was allowed to absorb 50 lb of distilled water, and the resulting mass of large gel particles was stirred with a 2-hp air stirrer while further additions of water were made to give a final dispersion containing 3 % solids. The dispersion was poured into trays sprayed with silicone mold release, and the trays were placed in a Virtis SRC-42 freeze drier. When the drying process was complete, there remained a continuous fibrous mat (8.4 % moisture) which absorbed 600 g of distilled water per g.

2.9. Procedure to Measure Absorbency

To evaluate water absorbency for dry, ground Super Slurper under free draining conditions, 0.25 g of sample is sifted into 500 ml of distilled water and allowed to soak for a measured length of time. The mixture is then poured onto a fine-mesh sieve fitted with a collecting pan. The unabsorbed water is collected and weighed and the grams of water absorbed per g of dry polymer is calculated. A similar

procedure is followed to determine the absorption of an electrolyte solution. One gram of absorber is soaked in 100 ml of electrolyte solution and poured through a sieve; the excess electrolyte solution is collected and measured. For either fluid, more than 50 % of capacity is reached in 30 s. Rate of absorption is, of course, related to particle size.

3. Results and Discussion

More polymer heterogeneity than usual can be expected with grafted polymers, since, in addition to molecular weight dispersity, one can expect chemical composition dispersity ranging from homopolymers to polymers composed of equal proportions of the components. Increased heterogeneity is expected when the grafted polymers are subjected to chemical modification, as is true of our process; reproducibility of product properties could thus be endangered. In our laboratory preparations [9, 10] we attempted to exercise some control over dispersity by repeated extractions of the S-PAN graft copolymer prior to alkaline hydrolysis and by again extracting the hydrolyzed graft copolymer in its water-insoluble, free carboxylic acid state. However, such procedures did not appear practical for large-scale preparations, so we designed a single vessel procedure for a crude product with no extraction steps.

Distilled water was used, because preparations with tap water gave highly colored, lower performance products. The ceric ammonium nitrate-nitric acid solution was prepared immediately before use since the ceric complex has limited stability in dilute acid or water. Ceric ammonium nitrate is used to form complexes with starch: decomposition of these complexes result in free radicals which serve to initiate polymerization. Graft polymerizations using 6 to 7 % starch dispersions resulted in 12 – 13 % graft copolymer dispersions. While it is possible to graft polymerize at higher starch concentrations, 12 – 13 % graft copolymer concentration was maximum for successful hydrolysis in our equipment. AN was added to the starch dispersion and stirred for 5 to 10 min prior to the addition of initiator to assure good distribution of monomer. The proportions used allowed the AN, which forms a 7.3 % solution in water at 20 °C [12], to dissolve.

When the polymerization is over, there usually remains a small amount, about 5 %, of monomeric AN dispersed in the colloidal graft mixture. Since toxic acrylamide is a possible product from hydrolysis of unpolymerized AN, it is necessary to remove this AN before hydrolysis is begun. We found a convenient and efficient method for AN removal to be steam distillation. The reaction mixture is first neutralized to avoid acid hydrolysis of the starch moiety, and antifoam is added because considerable foaming occurs without it. AN forms an azeotrope with water which boils at 160 °F and contains 88 % AN. Careful distillation would permit almost complete recovery of unpolymerized AN in a form suitable for reuse in the grafting step. When this distillation procedure was used, we obtained products, following alkaline hydrolysis and isolation by drum drying or alcohol precipitation, which gas-liquid chromatographic measurements showed to have no detectable AN and less than 10 ppm acrylamide.

Following the distillation step, the reaction mass was cooled to 160 – 170 °F to prevent too rapid a reaction when the alkali was added, and water was added to make up for losses during steam distillation. Following addition of alkali, temperature of the reaction mixture was raised to 195 – 205 °F and maintained for 1 h. The development of a deep-red color and its gradual disappearance during hydrolysis has been described previously [9]. It is during the final stage of hydrolysis that ammonia is evolved. Procedures to efficiently remove ammonia would increase recoverable byproduct and also decrease the amount of acid required for neutralization, thus giving a crude product with lower extraneous salt content.

When hydrolysis is complete, the heavy, doughlike material in the mixer contains 16 – 20 % solids and has a pH of approximately 12. In this alkaline state, the wet dough can be stored indefinitely; however, if the mixture is adjusted to pH 6.5 – 8.5 (usually with acetic acid), as is necessary before drum drying, the wet mixture becomes an excellent growth medium for microorganisms and therefore must be stored in the cold and only for a short time.

Super Slurper was isolated from the doughlike reaction mass by a number of different methods. Drum drying the reaction mass was a convenient method for preparing a crude product. Alcohol precipitation gave a higher absorbency product due in part to removal of extraneous salts. We have not attempted to develop a practical procedure for producing refined Super Slurper by alcohol washing of crude hydrolysate; however, small batches were precipitated using 95 % ethanol. Ethanol was used for precipitation because facilities were not available to handle the more toxic alcohols such as methanol, although we recognize the economic advantages of their use. For a commercial process, we visualize precipitation with methanol followed by drying at elevated temperatures to facilitate removal of methanol from the solid product. Super Slurper could also be prepared as a film or as a freeze dried mat (see Experimental).

To obtain information about some of the many variables in our process, we prepared a number of products on a small scale using a 1-1/2 ft^3 ribbon blender (Experimental) and compared their absorbencies (Table 1). The method used to measure absorbency (see Experimental) is designed to give an approximation and not a precise value. Absorbencies are similar with the exception of the low value in the last entry, for which the AN/glucose unit (GU) molar ratio of 1.65 was lower than the usual 3.30. Conversely, in the first entry, where a ratio of 6.60 was used, the absorbency value of 528 is very nearly the average value of the remaining entries. We concluded that limiting our AN/GU ratios to between 3.2 and 3.6 (or that ratio designed to give a S-PAN graft polymer composed of about equal weights of the two moieties) would give us information of the greatest practical value. When absorbencies are compared, it is apparent that a variety of whole starches can be used almost interchangeably. Either NaOH or KOH gives satisfactory hydrolysis, and products having either cation perform well. Alkali : AN molar ratios reported [9, 10] for the hydrolysis of S-PAN

Table 1. Data Obtained from Preparations Using 1-1/2 ft³ Blender[1].

Starch	AN/GU[2]	% N in graft	Alkali/AN[2]	% N in slurper	% Na or K in slurper	Isolation method	Absorbency (g H_2O/g)
Amioca	6.60	16.17	0.80[3]	4.85	11.09	MeOH	528
Amioca	3.30	—	0.80[3]	4.15	9.91	MeOH	588
Corn	3.30	12.99	0.80[3]	4.47	9.11	MeOH	416
Corn	3.30	—	0.80[4]	3.65	15.97	MeOH	600 (200)[5]
Corn	3.30[6]	14.55[7]	0.80[3]	4.87	—	iso-PrOH	600 (204)[5]
Corn	3.29	14.60	0.80[4]	—	—	EtOH	444
Corn	3.29	13.02	0.71[4]	—	—	EtOH	504
Wheat	3.15	12.11	0.60[3]	4.71	9.71		(176—292)[5]
Corn	1.65	—	0.71[4]	—	—	EtOH	168

1) Preparations were made using 11.4 g-moles of starch glucose unit (GU); 0.01 moles ceric initiator per GU; 0.01 moles HNO_3 per GU (g-unit wt. of GU = 162).
2) Molar ratio.
3) NaOH.
4) KOH.
5) Drum dried.
6) Used 0.008 moles ceric initiator per GU and 0.082 moles HNO_3 per GU.
7) $[\eta]_{DMF}$ was determined for isolated PAN moiety of this graft and found to be 9.2.

range from 2.5 to 10; however, we now have lowered this ratio to 0.6. This lower ratio is more economical and gives a product with less extraneous salt.

The results of 5 duplicate preparations are given in Table 2. Although there is variation in percent solids after steam distillation and in weights of recovered wet and dry products, these latter variations are due partly to machine losses. The compositions of the crude graft copolymers, as indicated by percent PAN and percent N, were similar, as were the absorbencies. As expected, the percent volatiles were diverse, since products were air-dried under ambient

Table 2. Data Obtained from Duplicate Preparations Using 1-1/2 ft³ Ribbon Blender[1].

Starch[2] conc. (%)	Solids after steam distillation (%)	PAN[3] in crude graft (%)	N in crude graft (%)	Wet product[4] (lb)	Dry product[5] (lb)	Volatiles in product (%)	Absorbency, as is (g H_2O/g)	Absorbency, corrected for volatiles (g H_2O/g)
6.3	11.2	46.3	12.71	67	11.25	13.8	407	473
6.0	10.3	46.4	13.10	77	10.25	15.7	416	495
5.9	9.9	46.8	12.96	—	12	19.8	360	450
6.2	11.2	46.5	12.63	78	11.5	14.6	368	433
6.2	9.8	44.5	12.25	77	10.25	13.6	364	423

1) Preparations were made using 11.45 g-moles of corn starch GU; 0.01 mole ceric initiator; 3.29 moles AN per GU; 0.71 moles KOH per mole of AN.
2) After gelatinization.
3) Determined gravimetrically after removing starch by acid hydrolysis.
4) After alkaline hydrolysis.
5) After alcohol precipitation.

conditions. The use of heat in the drying step was avoided, because after isolation Super Slurper loses some absorbency with extended exposure to elevated temperature. To demonstrate this, a product was placed in a Cenco Moisture Analyzer at 250 °F for periods varying from 2 to 60 min. Loss of volatiles ceased after 15 min, with the majority gone after 10 min; but, diminution of absorptive capacity continued for 60 min as shown in Figure 5.

AN to glucose unit (GU) mole ratios varied from 3.169 to 3.693 (Table 3), but within this narrow range we noted no marked effect on water absorbency of the final products. The lowest initiator-to-starch ratio used was 0.0076 moles of ceric ammonium nitrate (Ce^{+4}) per GU. Following the addition of initiator solution, an exotherm occurred. This is shown in Figure 6 for two different preparations. The peak temperature occurs after 30 min.

A time study of polymerization was carried out by withdrawing samples of the reaction mixture at intervals. A

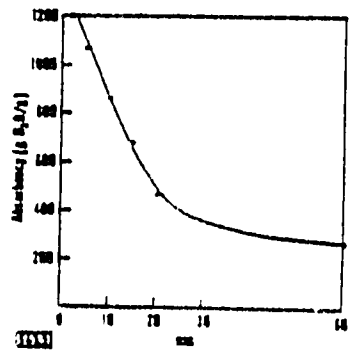

Figure 5. Effects of elevated (250 °F) temperature on absorbency.

GU[1] wheat starch	Ce^{+4}[2] / GU	AN[2] / GU	KOH[2] / AN	Lb product[3]	Absorbency (g H_2O/g product) Drum dried	Alcohol ppt	Dialyzed
0.183	0.0076	3.552	0.574	91	289 (700)[4]	592 (1300)[4]	
0.183[6]	0.0076	3.552	0.574	90	299	508 (1413)[4]	
0.183	0.0076	3.552	0.574	92[6]	268		
0.183	0.0076	3.552	0.574	—[6]	265		
0.183	0.0076	3.552	0.574	100[6]	252		
0.183	0.0076	3.552	0.580	94		608	
0.183	0.0076	3.552	0.577[7]	89	(536)[4]		
0.183[6]	0.0152	3.552	0.580	85	332	856	
0.183	0.0093	3.169	0.629	86[6]	352		1500 (500)[9]
0.183	0.0093	3.169	0.629	86[6]	352		1620 (996)[9]
0.183	0.0093	3.169	0.629	86[6]	300		1672 (872)[9]
0.183	0.0093	3.169	0.574	83	258	520	
0.183	0.0093	3.169	0.851	95	224		1412
0.177[10]	0.0096	3.277	0.574	76		652	
0.177[10]	0.0096	3.277	0.629	84		(852)[4]	

1) Based on a lb.-unit wt. of 162 for the glucose unit (GU)
2) Molar ratio.
3) Calculated on dry basis.
4) Mechanically sheared in Hydrapulper.
5) Starch gelatinized in continuous cooker.
6) Includes acetic acid added to adjust pH.
7) NaOH.
8) Waxy maize starch.
9) Crude product tray-dried at dialysis concentration.
10) Corn starch.

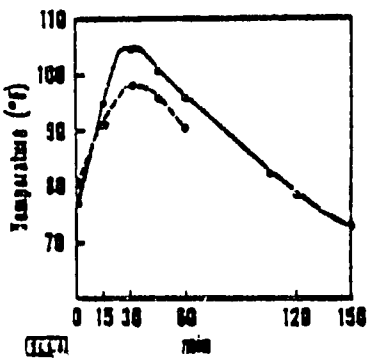

Figure 6. Exotherm. The temperature of graft polymerization mixture plotted against time. Results of two runs are shown, and in both instances peak temperature occurs after 30 min. Solid line = Run No. 1, Table 3. Broken line = Run No. 2, Table 3.

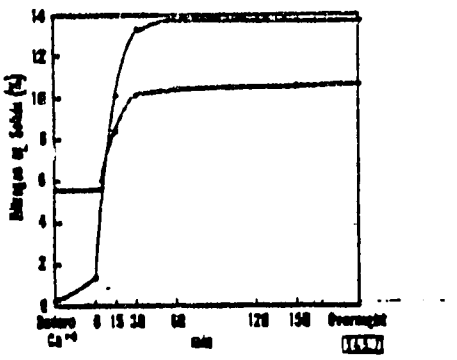

Figure 7. Time study of graft polymerization of acrylonitrile to starch (First Run, Table 3). Polymerization has nearly ceased after 30 min. Solid line gives % nitrogen plotted against time. Broken line gives % solids plotted against time.

50 ml sample of graft mixture was added to 10 ml of 5 % hydroquinone solution and the sampler was rinsed with 10 ml of water. Solids determinations on the aqueous dispersions were made using a Cenco Moisture Analyzer, and the observed increase in percent solids proved to be a convenient, rapid method for measuring polymerization which gave results comparable to analytical results. Figure 7 gives the results of both of these methods, and it should be noted that virtually all polymerization occurs in the first 30 min. This is the same time period of temperature rise shown in Figure 6; therefore, temperature rise can be used to monitor the reaction, and polymerization can be presumed to be over when the temperature begins to fall.

When the high pH hydrolysis product is subjected to mechanical shearing in a Hydrapulper, the viscosity of the doughlike material is reduced until there is obtained a smooth-flowing dispersion which can be readily diluted and pH-adjusted either for applying to substrates, such as cellulosics or clays, or for final processing to a dry product. Sheared products have high absorbencies comparable to dialyzed products, as can be seen in Table 3. We were able to shear mixtures having from 5 to 15 % solids to give products with comparable absorptive capacity; however, when shearing was carried out at the highest solids level, it was extremely difficult to remove the mixture from the Hydrapulper, which depends on gravity flow to empty. During shearing, considerable heat is generated (Fig. 8), and additional ammonia is evolved.

Portions of wet dough from a single preparation made in the 10-ft³ blender were isolated by three different methods: drum drying, alcohol precipitation, and Hydrapulper shearing followed by alcohol precipitation. Analyses of the dry isolates are presented in Table 4. As expected, the K content is less for precipitated products because monomolecular K salts have been largely removed. Since the material sheared in the Hydrapulper and then precipitated has a higher per-

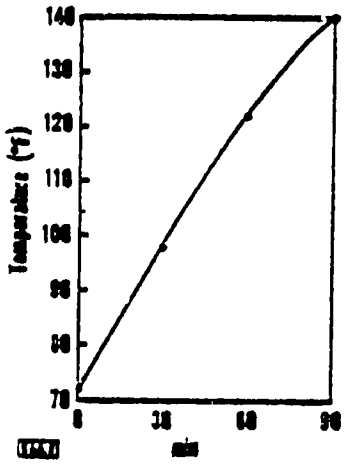

Figure 8. Effects of shearing in Hydrapulper on temperature. The temperature of hydrolyzed starch-polyacrylonitrile mixture plotted against shearing time.

cent K but lower percent C and N than the unsheared material, one might conclude that some further hydrolysis of amide groups has occurred during the shearing step.

Table 4. Analytical Findings for Different Isolates from First Run Listed in Table 3.

Isolation method	% C	% N	% Ash (calc. as K)
Drum dried	39.19	3.85	14.84
Alcohol ppt	42.47	4.16	12.19
Hydrapulper (6.4 %)[1]-alcohol ppt	40.64	4.08	13.83

1) Concentration after hydrapulping.

To summarize, we have found that a product prepared without intermediate isolation steps is as absorbent as one prepared with such steps. Our study indicates that a graft copolymer having equal portions of PAN and starch is appropriate for preparing Super Slurper. Lower proportions of PAN gave a product with low absorption; however, higher PAN content (e.g., 2 PAN to 1 starch) did not give products with higher absorbencies. A critical step in Super Slurper preparation is the final processing stage. For instance, mechanical shearing to produce good dispersion and release of byproduct ammonia prior to pH adjustment and isolation gave products with highest absorptive capacity. Drying temperatures were also important, since long exposure (in excess of 3 to 5 min) to high temperature, when moisture content was low, steadily decreased absorptive capacity.

4. Preliminary Cost-to-Make Estimate

A preliminary cost estimate for producing crude flakes (Experimental) of drum-dried Super Slurper indicates that for a hypothetical plant with an annual capacity of 10 million lb of product (5 % moisture), the cost to make is about $0.32/lb, when starch is priced at $0.10/lb, and the predicted yield of product with 5 % moisture is 317 lb/100 lb of commercial starch (Table 5). Estimated fixed capital investment for a battery limits installation (includes only equipment and other facilities directly associated with the process) for producing 10^7 lb/year of crude flakes is $2,500,000.

Table 5. Estimated Cost-to-Make Crude Drum-Dried Flakes of Super Slurper[1] in a Plant[2] with 10^7 lb/year Capacity Operating 24 h/day, 250 days/year.

Cost item			$/lb of crude flakes
Raw materials			
lb	Reactant	$/lb	
100	Starch	0.10	0.032
2.34	Ceric ammonium nitrate	2.60	0.019
Nominal	Nitric acid	0.11	—
103.5	Acrylonitrile	0.27	0.028
133.5	47 % Potassium hydroxide	0.075	0.032
24	Acetic acid	0.15	0.011
317[3]			
Utilities (steam $ 2.00/M lb, elec. $ 0.03/kwh, water $ 0.30/M gal)			0.038
Labor and supervision (operators $ 7.00/h)			0.033
Maintenance			0.014
Fixed charges (depreciation 10 %/year, taxes and insurance, 3 %/year)			0.031
General plant overhead			0.024
		Estimated cost-to-make	0.322

1) Procedure I, Experimental.
2) Estimated fixed capital investment: $ 2,500,000 for battery limits installation.
3) Predicted yield of product including 5 % moisture.

Table 6. Estimated Cost-to-Make Refined Powdered Super Slurper[1] in a Plant[2] with 10^7 lb/year Capacity Operating 24 h/day, 250 days/year.

Cost item			$/lb of refined powder
Raw materials			
lb	Reactant	$/lb	
100	Starch	0.10	0.034
2.34	Ceric ammonium nitrate	2.60	0.021
Nominal	Nitric acid	0.11	—
103.5	Acrylonitrile	0.27	0.095
133.5	47 % Potassium hydroxide	0.075	0.034
3.0	Acetic acid	0.15	0.004
	Methanol[3]	0.42/gal	0.027
294[4]			
Utilities (steam $ 2.00/M lb, elec. $ 0.03/kwh, water $ 0.30/M gal)			0.052
Labor and supervision (operators $ 7.00/h)			0.059
Maintenance			0.022
Fixed charges (depreciation 10 %/year, taxes and insurance, 3 %/year)			0.050
General plant overhead			0.041
		Estimated cost-to-make	0.449

1) Procedure II, Experimental.
2) Estimated fixed capital investment: $ 4,000,000 for battery limits installation.
3) Based on 4 % loss.
4) Predicted yield of product including 10 % moisture.

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A rough cost estimate for producing refined powder form of Super Slurper (Experimental), which includes methanol-washing of the wet crude material, shows that for a hypothetical plant having a capacity of 10^7 lb/year of refined product (10 % moisture), the cost-to-make is about $0.45/lb of product (Table 6). Yield of product with 10 % moisture is predicted to be 294 lb/100 lb of commercial starch. Estimated fixed capital investment for a battery limits installation to produce 10^7 lb/year of refined powder is $4 million.

Both hypothetical plants are considered to be adjuncts to an existing processing plant. Costs are reported as of late 1976 and cost items included in the estimated cost-to-make are: raw materials, utilities, labor and supervision, maintenance, fixed charges and general plant overhead.

In this estimate, it is assumed that combined time for grafting and saponification is 4 h. It is likely that this time can be reduced, and the process may be suitable for continuous operation, at least in part. No credit has been given in the estimate for the AN, which is removed and recovered through steam distillation; however, the cost for its removal is included as part of the production cost. How the ammonia that is removed at the end of the hydrolysis step will be disposed of or recovered has not been resolved. Also, the cost for its recovery has not been included, and no by-product credit has been given for it.

A complete practical procedure for producing alcohol precipitated Super Slurper has not been developed. Alcohol precipitation, mostly with low toxicity ethanol, has been carried out in small batches, but no attempt has been made to optimize the process. Our estimate assumes the use of 10 lb of methanol per lb of product, isolation of the product by centrifugation, and an expected overall loss of 4 % alcohol. It is assumed that the alcohol in the centrifugates will be combined with that recovered from the drying step and will be distilled to give anhydrous methanol, which will be recycled in the process. Studies are necessary to determine the minimum amount of alcohol required to obtain an acceptable product.

Raw materials represent 54 % of the total estimated cost to make crude flakes; and AN, when priced at $0.27/lb, represents 27 % of the total. Estimation for the refined product sets raw materials at 48 % of total and AN at 21 %. Starch at $0.10/lb represents 10 % and 3 % of the cost of crude and refined products, respectively. Prices for raw materials other than starch and ceric initiator were obtained from Chemical and Marketing Reporter. Prices for starch and ceric initiator were obtained by communication with suppliers.

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The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

Zusammenfassung

Ein praktisches Verfahren zur Herstellung von „Super-Slurper", einem Polymer auf Stärkebasis mit großem Wasserbindungsvermögen. Das feste, wasserlösliche, in Wasser quellende Adsorbens „Super-Slurper" ist ein basenhydrolysiertes Stärke-Pfropfcopolymer, in welchem die Nitrilfunktion in eine Mischung aus Carbonamid und Alkalimetallcarboxylat umgewandelt wurde. Ausgehend von Untersuchungen im Laboratoriumsmaßstab wurde ein Verfahren zur Herstellung des Polymers in Kilogramm-Mengen entwickelt. Das Verfahren vermeidet intermediäre Isolierungsstufen, erlaubt die wirksame Entfernung des nicht umgesetzten Monomers, hält die Konzentration an überschüssigen Salzen niedrig und ermöglicht eine hohe Feststoffkonzentration in der Trocknungsstufe. Abwandlungen des Trocknungsverfahrens ermöglichen die wahlweise Herstellung von „Super-Slurper" in Film-, Matten-, Pulver- oder Flockenform. Das Abscheren des Hydrolysengemisches vor der Isolierung und das Vermeiden der längeren Einwirkung von höherer Temperatur auf das isolierte Produkt ergibt „Super-Slurper" mit höchster Absorption-kapazität. Die verwendete Apparatur entspricht der industriellen Praxis. Die Kosten für die Herstellung von trommelgetrockneten Flocken in einem hypothetischen Betrieb für 10^7 lb/Jahr werden auf $ 0,32/lb geschätzt.

Résumé

Un procédé pratique pour la préparation de „Super Slurper", un polymère à base d'amidon avec une grande capacité d'absorption d'eau. L'absorbant solide insoluble dans l'eau, dénommé „Super Slurper", est un copolymère greffé à base d'amidon-polyacrylonitrile, hydrolysé par une base, dans lequel la fonction nitrile a été transformée en un mélange de carboxamide et de carboxylate métallique alcalin. A partir des expériences de laboratoire, un procédé qui permet la production de plusieurs kilos a été mise au point. Ce procédé évite les étapes intermédiaires d'isolement, permet l'élimination efficace du monomère non transformé, maintient une faible concentration en matière sèche élevée pour l'étape de séchage. La variation du procédé de séchage permet d'obtenir le „Super Slurper" sous forme de films, de plaques de poudre ou de flocons. Le cisaillement du mélange hydrolysé avant l'isolement et la précaution de ne pas exposer le produit isolé à des températures élevées conduisent à l'obtention d'un „Super Slurper" ayant la plus grande capacité absorbante. L'équipement utilisé correspond à la pratique industrielle. Les coûts de fabrication de flocons séchés sur tambour dans une usine hypothétique produisant 10^7 lb/année sont estimés à 0.32 dollar/lb.

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Absorbent Polymers from Starch and Flour Through Graft Polymerization of Acrylonitrile and Comonomer Mixtures

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Polyacrylonitrile (PAN)-containing graft copolymers of corn starch were prepared from monomer mixtures and then saponified, and dried. Incorporation of selected comonomers lead to shorter saponification times and higher yields of adsorbent products. Substitution of flour for starch gave products which had a higher absorbency than saponified starch-g-PAN.

Absorptionspolymere aus Stärke und Mehl durch Pfropfpolymerisation von Acrylnitril- und Co-Monomergemischen. Polyacrylnitril (PAN) enthaltende Pfropf-Copolymere von Maisstärke wurden aus Monomergemischen dargestellt, verseift und getrocknet. Die Mitverwendung bestimmter Co-Monomere führte zu verkürzten Verseifungszeiten und höheren Ausbeuten an adsorbierten Produkten. Die Substitution von Stärke durch Mehl führte zu Produkten mit höherer Absorptionsfähigkeit als verseiftes Stärke-g-PAN

1 Introduction

Graft copolymers of polyacrylonitrile (PAN) and starch, containing about equal weights of the two components, are readily prepared by allowing acrylonitrile to react with starch in an aqueous system in the presence of ceric ammonium nitrate initiator [1]. Only a small amount of ungrafted PAN is formed as a byproduct. When starch-g-PAN is treated with hot alkali, the nitrile substituents of PAN are saponified to a mixture of alkali metal carboxylate and carboxamide [2]. Isolation and drying of this saponified polymer affords a product which will absorb several hundred times its own weight of water while still remaining insoluble [3]. Films prepared by air-drying water dispersions of saponified polymer will retain their integrity when they imbibe water and will swell to form continuous sheets of gel [4]. The remarkable ability of saponified starch-g-PAN to absorb large amounts of aqueous fluids has generated considerable interest. Suggested uses for saponified starch-g-PAN range from incorporation into personal care products, such as disposable diapers, to agricultural uses, such as seed and root coating and addition to sandy soils to improve water retention.

Current research on saponified starch-g-PAN and other starch-containing absorbent polymers at the Northern Regional Research Center has as its goals the improvement of absorbent properties and salt tolerance, the simplification of synthetic methods, and the correlation of polymer structure with absorbent properties. In this report, we will discuss the preparation of high absorbency graft copolymers by the substitution of flour for starch [5]. We also will describe the higher absorbencies and the simplified synthetic procedures which result when selected comonomers are included with acrylonitrile during graft polymerization.

2 Experimental

2.1 Materials

Globe pearl corn starch (Globe 3005) was from CPC International, and pregelatinized wheat starch was MSWS-1000 from Midwest Solvents. Yellow corn flour, bleached pregelatinized corn flour, and whole ground corn meal were from Illinois Cereal Mills. Soft wheat flour was from King Milling Company and contained 1.66% nitrogen and 0.5% ash.

Acrylonitrile, Eastman practical grade, was distilled at atmospheric pressure through a 14-in. Vigreux column, and a center cut was collected and stored at 5 °C. Reaction grade 2-acrylamido-2-methylpropanesulfonic acid ($AASO_3H$) was from The Lubrizol Corporation, acrylamide was Eastman reagent grade, and vinylsulfonic acid was a 40% aqueous solution from Polysciences, Inc. These three monomers were

used as received. Acrylic acid, methyl acrylate, methyl methacrylate and styrene were Eastman reagent grade and were distilled before use.
Ceric ammonium nitrate was Fisher Certified ACS grade.

2.2 Graft Polymerization of Acrylonitrile and Comonomer Mixtures

A stirred slurry of 10.0 g, dry basis, of either corn starch, flour, or meal in 167 ml of water was heated for 30 min at 85 – 87 °C while a slow stream of nitrogen was allowed to bubble through the mixture, and the mixture was then cooled back to 25 °C. For experiments performed with granular starch or flour, the stirred water slurry was purged with nitrogen for 1 h at 25 °C. Either 15.0 g (0.283 mole) of acrylonitrile or a mixture of acrylonitrile and a comonomer (0.283 mole total) was added to the starch or flour suspension, followed after about 1 min by a solution or 0.338 g (6.17×10^{-4} mole) of ceric ammonium nitrate in 3 ml of 1-N nitric acid. The reaction mixture was allowed to stir under nitrogen for 2 h, and in most reactions, sodium hydroxide solution was then added to give a pH of 7. The mixture was diluted with 200 ml of ethanol and the crude graft copolymer was isolated by filtration, washed with ethanol and dried *in vacuo* at 60 °C. Weight percent synthetic polymer in the crude graft copolymer (% add-on) was calculated from the gain in weight due to graft polymerization.
Selected crude graft copolymers were subjected to repeated extractions at room temperature with dimethylformamide (DMF) to remove ungrafted synthetic polymer, and the weight percent of the total product which was soluble in DMF was calculated.

2.3 Saponification of PAN-Containing Graft Copolymers and Isolation of Absorbent Polymers

Dialyze and Tray Dry: A suspension of 1.00 g of crude (unextracted) graft copolymer in 20 ml of 0.5-N sodium hydroxide solution in a 125-ml Erlenmeyer flask was heated on a steam bath until the mixture assumed a red-orange color and thickened sufficiently to preclude settling on standing (about 5-15 min heating was required). The flask was loosely stoppered, to permit escape of ammonia, and was then placed in a 95 – 100 °C oven for 2 h. The length of time in the oven needed to cause the red-orange color to fade to a light yellow (an indication that saponification had gone to completion) was noted. The reaction mixture was diluted with about 400 ml of water and dialyzed against distilled water until the pH of the dispersion was 6.4 – 7.2. The dispersion was then poured onto a Teflon-coated tray and dried to a thin film in a forced air oven at about 35 – 40 °C.
Drum Dry Unpurified Product: A suspension of 4.00 g of graft copolymer in 50 ml of 0.5-N sodium hydroxide solution was heated on a steam bath for 10 – 15 min and was then heated in a 95 – 100 °C oven for 3.5 h. After the reaction mixture had stood overnight at room temperature, glacial acetic acid was added to give a pH of 6.9 – 7.2. The reaction mass was then dried on a 7 – 5/8 × 6 in. diameter double-drum drier with a 0.003 in. gap separating the drums. Drums were rotated at 3 rpm and were heated with 40 psig steam.
Tray Dry Unpurified Product: A suspension of 2.00 g of graft copolymer in 25 ml of 0.5-N sodium hydroxide solution was heated on a steam bath for 10 – 15 min and was then heated in a 95 – 100 °C oven for 2.5 h. The reaction mass was dispersed in 200 ml of water and glacial acetic acid was added to give a pH of 8.0 – 8.9. The dispersion was poured onto a Teflon-coated tray and dried to a thin film in a forced air oven at about 35 – 40 °C.
Methanol Precipitate: A suspension of 1.00 g of graft copolymer in 9 ml of 0.7-N sodium hydroxide solution in a 25 ml Erlenmeyer flask was heated on a steam bath for 5 – 10 min and was then heated in a 95 – 100 °C oven for 3 h. The reaction mass was stirred at high speed for 1 min in a Waring Blendor with 350 ml of absolute methanol, and the precipitated solid was collected on a filter. The solid was triturated in a mortar and pestle with fresh methanol; after the resulting slurry had stood for 10 min, the solid was removed by filtration and allowed to air dry at 22 °C and 50% relative humidity. Since variations in methanol content affected water absorbencis, polymers were allowed to equilibrate for at least 3 days until constant absorbency values were obtained.

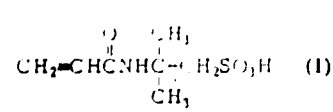
2.4 Measurement of Fluid Absorbency

To determine water absorbency of dried, saponified polymers, an accurately weighed 2 – 20 mg sample of polymer (amount used depended on absorbency) was allowed to soak for 30 min in 50 ml of deionized water. The swollen polymer was then separated from unabsorbed water by screening through a tared 280 mesh sieve which was 4.8 cm in diameter. The polymer on the sieve was allowed to drain for 20 – 30 min, and the sieve was then weighed to determine the weight of water-swollen gel. Absorbency was calculated as grams of water per gram of polymer. No correction for moisture content of the polymer (about 10 – 20%) was applied. Polymers with absorbencies over 1000 g/g had to be handled with extreme care to avoid break-up of the highly swollen films or particles and subsequent clogging of the sieve. A similar absorbency test was run in simulated urine (0.64 g $CaCl_2$, 1.14 g $MgSO_4 \cdot 7H_2O$, 8.20 g NaCl, 20.0 g urea and 1000 g deionized water) with about 75 mg of polymer.

3 Results and Discussion

3.1 Use of Comonomers in Graft Polymerization

Selected comonomers were graft polymerized along with acrylonitrile onto both granular and gelatinized corn starch in the presence of ceric ammonium nitrate to give graft copolymers containing about 50 – 60%, by weight, of synthetic polymer. Graft polymerizations of monomer mixtures containing 1 – 10 mole % (3.8 – 30.1 weight %) of $AASO_3H$ (see the following structural formula (1)) are shown



(1)

in Table 1 along with the times needed for alkaline saponification and the absorbencies of the products, as expressed in grams of absorbed fluid per gram of polymer. For convenience, absorbent polymers in Table 1 were isolated by dialyzing the saponification mixtures until a near neutral pH was obtained and then drying the resulting dispersions near room temperature to thin films on Teflon-coated sheets.

When any PAN-containing graft copolymer is heated in alkali, a red-orange color rapidly develops due to initial formation of highly conjugated ring structures [6]. At the end of the saponification, the red-orange color fades to a light yellow, and this color change thus serves as a good indicator of reaction completeness. Although saponifications in Table 1 were arbitrarily run for 2 h at 95 – 100 °C, the saponification

Table 1.
Graft Copolymerization of Acrylonitrile and 2-Acrylamido-2-Methylpropanesulfonic Acid onto Corn Starch. Absorbency of Saponified Polymer

Number	Mole % $AASO_3H$[1]	Weight % $AASO_3H$	Starch granule state	Add-on[2] (%)	DMF solubles[3] (%)	Saponification time[4] (min)	Absorbency (g fluid per g polymer)[5]	
							H_2O	synthetic urine
0-Gr	0	0	Granular[6]	55	2.5	75	300	28
0-Gel	0	0	Gelat.[7]	59	12	90	1000	40
1-Gr	1	3.8	Granular	57	4.3	–[8]	380	33
1-Gel	1	3.8	Gelat.	58	8.8	65	1300	58
5-Gr	5	17.0	Granular	56	9.3	–	570	39
5-Gel	5	17.0	Gelat.	56	9.7	32	2900	62
10-Gr	10	30.1	Granular	54[9]	16	30	970	47
10-Gel	10	30.1	Gelat.	58[10]	–	28	5300	73

1) $AASO_3H$ = 2-acrylamido-2-methylpropanesulfonic acid.
2) Weight % synthetic polymer in the dry reaction product.
3) Weight % of the dry reaction product dissolved by exhaustive extraction with dimethylformamide (DMF).
4) As indicated by the color change from red-orange to yellow. All saponifications were run for 2 h.
5) Isolated by dialysis and tray drying.
6) Starch-water slurry maintained at room temperature.
7) Starch-water slurry heated for 30 min at 85–87°C and then cooled to room temperature before graft polymerization.
8) Not determined.
9) Graft copolymer contains 0.71% sulfur.
10) Graft copolymer contains 1.29% sulfur.

times given in the tables are the times required for loss of the red-orange color.

Extraction of homopolymers from crude graft copolymers with DMF at room temperature removed, in most instances, less than 10% of each product as DMF solubles; moreover, these soluble fractions were not all homopolymer, as evidenced by carbohydrate absorptions in infrared spectra. Grafting efficiencies were therefore high in these polymerizations. Since each reaction mixture was neutralized to pH 7 before product isolation, poly($AASO_3H$) in the copolymer is largely in the DMF-insoluble sodium salt form, poly($AASO_3Na$), rather than as the free sulfonic acid. However, due to the solubility of PAN in DMF, we would expect that poly(acrylonitrile-*co*-$AASO_3Na$) would also be DMF-soluble at low concentrations of $AASO_3Na$. Alkaline saponifications were run on unextracted polymers.

Two important conclusions may be drawn from Table 1. First, the incorporation of $AASO_3H$ as a comonomer along with acrylonitrile gives graft copolymers which require significantly shorter saponification times. Shortening of reaction time is, of course, of critical importance if the absorbent polymer is to be produced economically on a large scale. Second, use of $AASO_3H$ in conjunction with acrylonitrile gives saponified graft copolymers from both granular and gelatinized starch which absorb larger amounts of aqueous fluids than their counterparts prepared from acrylonitrile alone. Use of gelatinized starch with a monomer mixture containing 10 mole % $AASO_3H$ results in a saponified polymer which will absorb over 5000 times its weight of deionized water. Granular starch with the same monomer mixture affords a saponified polymer which absorbs about as much water as saponified starch-*g*-PAN prepared from gelatinized starch but in the absence of comonomer. It is highly significant that polymers with absorbencies of almost 1000 g/g can be prepared without the need for starch gelatinization by simply including $AASO_3H$ in the polymerization recipe. Graft polymerization onto granular starch not only shortens processing time and saves energy which would be used to perform the gelatinization step, but also yields a granular graft copolymer which may be easily isolated from a reaction mixture by filtration or centrifugation, purified by water washing, and stored if necessary before alkaline saponification.

Since dialysis followed by tray drying would not be an acceptable isolation method for large-scale production of absorbent polymers, we examined some more practical methods for product isolation and determined how these methods effected water absorbency (Table 2). When crude saponification mixtures were drum-dried, with no further treatment other than to adjust the pH to near neutrality with glacial acetic acid, products had greatly reduced absorbencies, as compared with values in Table 1, and absorbency differences between individual products were not as large. In fact, when gelatinized starch was used, absorbencies were about the same regardless of the $AASO_3H$ content of the monomer mixture. With granular starch, significant increases in absorbency were realized with monomer mixtures containing 5 and 10 mole % $AASO_3H$.

Table 2.
Water Absorbencies of Saponified Polymers from Table 1. Dependence on Isolation Method.

Number[1]	Absorbency (g H_2O per g polymer)		
	Drum dried unpurified product	Tray dried unpurified product	Precipitate with methanol
0-Gr	180	–	230
0-Gel	320	430	1500
1-Gr	240	–	260
1-Gel	330	980	2600
5-Gr	320	–	590
5-Gel	290	1800	1800
10-Gr	350	–	1000
10-Gel	310	1600	2500

1) From Table 1.

A second method which we used to isolate absorbent polymers was to dilute the crude saponification mixtures with water, adjust the pH to near neutrality with acetic acid, and dry the resulting dispersions to thin films near room temperature on Teflon-coated sheets. If various substrates, e. g., cellulose fibers, paper, or clay, were to be coated with a small percentage of absorbent polymer to increase their absorbency, a drying method similar to this would probably be used. Although granular starch-based polymers were not isolated by this procedure, those derived from gelatinized starch showed large increases in absorbency when prepared with $AASO_3H$, even though the absorbency of the 10 mole % $AASO_3H$ product was lower than expected, based on Table 1. Since drying conditions used for these absorbent polymers were similar to those used for the dialyzed polymers of Table 1, differences in these two sets of absorbency data show the detrimental effects of inorganic salts on absorbency. The data also suggest that the low absorbencies of drum dried products are due to excessive heat during drying, since these and the drum-dried polymers have similar inorganic salt contents.

Finally, absorbent polymers were isolated by precipitation with methanol followed by air drying. Polymers prepared from gelatinized starch with 0 and 1 mole % $AASO_3H$ showed higher water absorbencies after methanol precipitation than they did after dialysis and tray drying, while those prepared with larger amounts of $AASO_3H$ showed higher absorbencies with the dialysis and tray-drying technique. Examination of granular starch-based products showed only minor differences in absorbency between the dialyzed and tray-dried samples of Table 1 and the methanol precipitated products of Table 2. If we consider the four methanol precipitated products from granular starch, it is obvious that incorporating $AASO_3H$ in graft polymerization mixtures leads to significantly higher water absorbencies. The beneficial effect of $AASO_3H$ on the absorbency of methanol precipitated polymers is less, however, when gelatinized starch is used.

Sulfur analyses were run on the granular and gelatinized starch graft copolymers prepared with 10 mole % $AASO_3H$, and these analyses showed that synthetic moieties contained only 2.3 and 4.2 mole % $AASO_3H$, respectively. Analyses of saponified graft copolymers, however, showed that 80 – 85% of these $AASO_3H$ repeating units were still present in the polymer and had not suffered alkaline saponification.

Although reaction mixtures were normally neutralized with sodium hydroxide before product isolation, we also ran a few graft polymerizations with $AASO_3H$ as a comonomer without neutralizing the acidic reaction mass before isolating and drying the product at 60°C. However, these graft copolymers gave saponified polymer films, after dialysis and tray drying, which in many instances were inferior as absorbents for deionized water, since they swelled to such a large degree that they lost their film integrity. It was thus logical to assume that the sulfonic acid groups in the synthetic polymer were causing hydrolysis of the starch moiety under the conditions of drying. Although these saponified graft copolymer films swelled excessively in water, many of them maintained their integrity and had good absorbent properties when placed in electrolyte solutions. For example, a saponified graft copolymer with 56% add-on prepared from a monomer mixture containing 5 mole % $AASO_3H$ and 95 mole % acrylonitrile absorbed 87 g of synthetic urine per gram of polymer.

If the percentage of $AASO_3H$ in the monomer mixture was sufficiently high, the resulting graft copolymers showed a high enough affinity for water to function as absorbents for aqueous fluids without saponification, even though the free sulfonic acid groups made the polymer-water system strongly acidic. For example, a graft copolymer with about 54% add-on prepared from a mixture of 31 mole % (63.6 weight %) $AASO_3H$ and 69 mole % acrylonitrile absorbed 580 times its weight of deionized water and 21 times its weight of synthetic urine. The pH of a viscous 0.67% dispersion of this polymer in water was 2.5. The ability of a graft copolymer of this type to swell and absorb water under highly acidic conditions is an extremely useful property not found in any of the saponified starch-g-PAN graft copolymers previously prepared. Indeed, when the sodium carboxylate groups of saponified starch-g-PAN are converted to the carboxylic acid form (usually at a pH of about 3), the polymer precipitates from dispersion as a rubbery mass, which shows a greatly reduced absorptive capacity for aqueous fluids [2].

Graft polymerizations of mixtures of acrylamide (10 or 20 mole %) and acrylonitrile onto both granular and gelatinized corn starch and the saponification of the resulting graft copolymers are shown in Table 3. Extraction with DMF removed only minor amounts of soluble polymer, and saponifications were run on the unextracted products. Although the absorbencies of tray dried films cast from the saponified graft copolymers after dialysis were in most cases the same or somewhat less than those of the corresponding products prepared in the absence of comonomer, the times needed for alkaline saponification were shortened considerably when acrylamide was included in polymerization mixtures. For example, a graft copolymer prepared from a mixture of 20 mole % acrylamide and 80 mole % acrylonitrile was completely saponified in a remarkable 12 – 13 min. Since all saponifications were arbitrarily run for 2 h, regardless of the time of the observed color change, the last saponification in Table 3 was rerun and the saponification mixture removed from the oven and worked up after 13 min to see if the shortened saponification time would adversely effect absorbency. The saponified polymer film absorbed 720 g of water per gram of polymer, in reasonable agreement with the value of 660 in Table 3.

Table 3.
Graft Copolymerization of Acrylonitrile and Acrylamide onto Corn Starch. Absorbency of Saponified Polymer.

Mole % AA[1]	Weight % AA	Starch granule state	Add-on (%)	DMF solubles (%)	Saponification time (min)	Absorbency (g fluid per g polymer)[2]	
						H_2O	Synthetic urine
0	0	Granular	55	2.5	75	300	28
0	0	Gelat.	59	12	90	1000	40
10	12.9	Granular	58	4.8	–	460	34
10	12.9	Gelat.	60	7.2	27	880	43
20	25	Granular	58	4.3	12	300	30
20	25	Gelat.	60	5.2	13	660	28

1) AA = acrylamide.
2) Isolated by dialysis and tray drying.

Five other monomers were copolymerized with acrylonitrile onto gelatinized corn starch to determine their effect on saponification time and on the absorbency of saponified graft copolymer films isolated by dialysis and tray drying (Table 4). Acrylic acid increased water absorbency of the saponified graft copolymers and shortened the time needed for saponification. A shortened saponification time was also obtained with 10 mole % methyl acrylate. Although inclusion

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Table 4.
Graft Copolymerization of Acrylonitrile and Selected Comonomers onto Gelatinized Corn Starch. Absorbency of Saponified Polymer.

Comonomer	Mole % comonomer	Weight % comonomer	Add-on (%)	Saponification time (min)	Absorbency (g fluid per g polymer)[1]	
					H_2O	Synthetic urine
None	0	0	59	90	1000	40
Vinylsulfonic acid	5	9.7	56	105	1200	49
Acrylic acid[2]	5	6.6	49	30	1500	42
Acrylic acid[3]	10	13.1	48	20	1600	47
Methyl acrylate	10	15.2	61	40	1000	38
Methyl methacrylate	10	17.3	60	95	440	26
Styrene	10	17.8	55	70	230	21

1) Isolated by dialysis and tray drying.
2) Twice the usual amount of ceric ammonium nitrate was required to initiate polymerization.
3) Four times the usual amount of ceric ammonium nitrate was required to initiate polymerization.

of vinylsulfonic acid also gave a saponified polymer with higher absorbency, the saponification time was somewhat longer. This was a surprising result, since one might expect behavior analogous to $AASO_3H$. When 10 mole% of either methyl methacrylate or styrene was included with acrylonitrile in the graft polymerization, absorbency values of the saponified products were lower than those of saponified starch-g-PAN, and there was little or no reduction in saponification time.

3.2 Graft Polymerization of Acrylonitrile onto Flour and Meal

Acrylonitrile was graft polymerized onto a series of flour and meal samples, which had either been slurried in water at room temperature or heated in water at 85 °C to gelatinize the starch component (Table 5). Comonomers were not used. With the exeption of the reaction with whole ground corn meal, which used twice the normal amount of ceric ammonium nitrate initiator, graft polymerizations were carried out in a manner identical to that normally used with starch and gave products with comparable values for % add-on.

A major difference between these reactions and previous polymerizations onto corn starch was the relatively high percentage of polymer which was dissolved on extraction with DMF. Infrared spectra of these soluble fractions showed them to be largely ungrafted PAN, with the exception of the fraction from the bleached pregelatinized corn flour product, which contained considerable carbohydrate. Since ungrafted PAN would not be removed from the graft copolymer before saponification in any practical process, the entire reaction product from graft polymerization was saponified to obtain the absorbent polymer.

Although it is apparent from Table 5 that saponification times have not been significantly shortened by substituting flour or corn meal for starch, the fluid absorbencies of saponified polymers isolated by dialysis and tray drying have been markedly increased by this substitution. Of particular interest is the absorbent polymer prepared from ungelatinized yellow corn flour, which had an absorbency almost equal to an analogous product prepared from gelatinized corn starch. Not only is flour often a cheaper raw material than starch, but omission of the gelatinization step would result in a significant cost savings in any commercial process.

As with the $AASO_3H$-containing polymers, we investigated some practical methods for the isolation of the absorbent polymers prepared from granular and gelatinized yellow corn flour and determined the effects of these isolation methods on water absorbency (Table 6). As observed in Table 2, drum drying of crude reaction mixtures produced polymers having relatively low absorbencies; only minor differences were found between flour-based polymers and starch-based polymers. When the unpurified reaction mixtures derived

Table 5
Graft Polymerization of Acrylonitrile onto Flour and Meal. Absorbency of Saponified Polymer

Number	Substrate	Pretreatment of substrate slurry (°C)	Add-on (%)	DMF solubles (%)	Saponification time (min)	Absorbency (g fluid per g polymer)[1]	
						H_2O	Synthetic urine
CF-Gel	Yellow corn flour	85	53	26	105	2600	57
CF-Gr	Yellow corn flour	25	40	22	>60	900	32
PCF	Bleached pregelat. corn flour	25	58	27	>60	2700	76
CM-Gel	Whole ground corn meal[2]	85	42	–	75	1900	39
WF-Gel	Soft wheat flour	85	52	34	>85	2100	44

1) Isolated by dialysis and tray drying.
2) Twice the normal amount of ceric ammonium nitrate was required to initiate polymerization

50
67

Table 6
Water Absorbencies of Flour-Based Polymers vs Starch-Based Polymers. Dependence on Isolation Method.

Number	Absorbency (g H_2O per g polymer)		
	Drum dried unpurified product	Tray dried unpurified product	Precipitate with methanol
0-Gr[1]	180	–	230
0-Gel[1]	320	430	1500
CF-Gr[2]	200	–	500
CF-Gel[2]	270	690	1200

1) From Table 2.
2) From Table 5.

from gelatinized flour and starch were tray dried, the use of flour in the graft polymerization resulted in a significant increase in absorbency. When absorbent polymers were isolated by methanol precipitation, the gelatinized flour-based polymer exhibited a lower water absorbency than its starch counterpart, in contrast to the results in Table 5 for dialyzed and tray dried films. The methanol precipitated absorbent from granular flour, however, showed a significantly higher absorbency than that prepared from granular starch.

We are indebted to *Clara E. Johnson* for sulfur analyses.

The mention of firm names or trade products does not imply that they are endorsed or recommended by the U. S. Department of Agriculture over other firms or similar products not mentioned.

Summary

Polyacrylonitrile (PAN)-containing graft copolymers of corn starch were prepared from monomer mixtures obtained when selected comonomers were substituted for a portion of the acrylonitrile. Graft copolymers were then saponified and the saponified polymers dried to form absorbents for aqueous fluids. Use of 2-acrylamido-2-methylpropanesulfonic acid as a comonomer resulted in shorter saponification times and more absorbent products. Incorporation of acrylamide into the polymerization mixture similarly shortened the time needed for saponification. Vinylsulfonic acid, acrylic acid, methyl acrylate, methyl methacrylate and styrene were also used as comonomers, and their effect on saponification time and on absorbency of the saponified polymer was examined. Substitution of flour or corn meal for starch in the ceric initiated graft polymerization of acrylonitrile gave polymers which, after saponification, had a higher absorbency for aqueous fluids than saponified starch-*g*-PAN.

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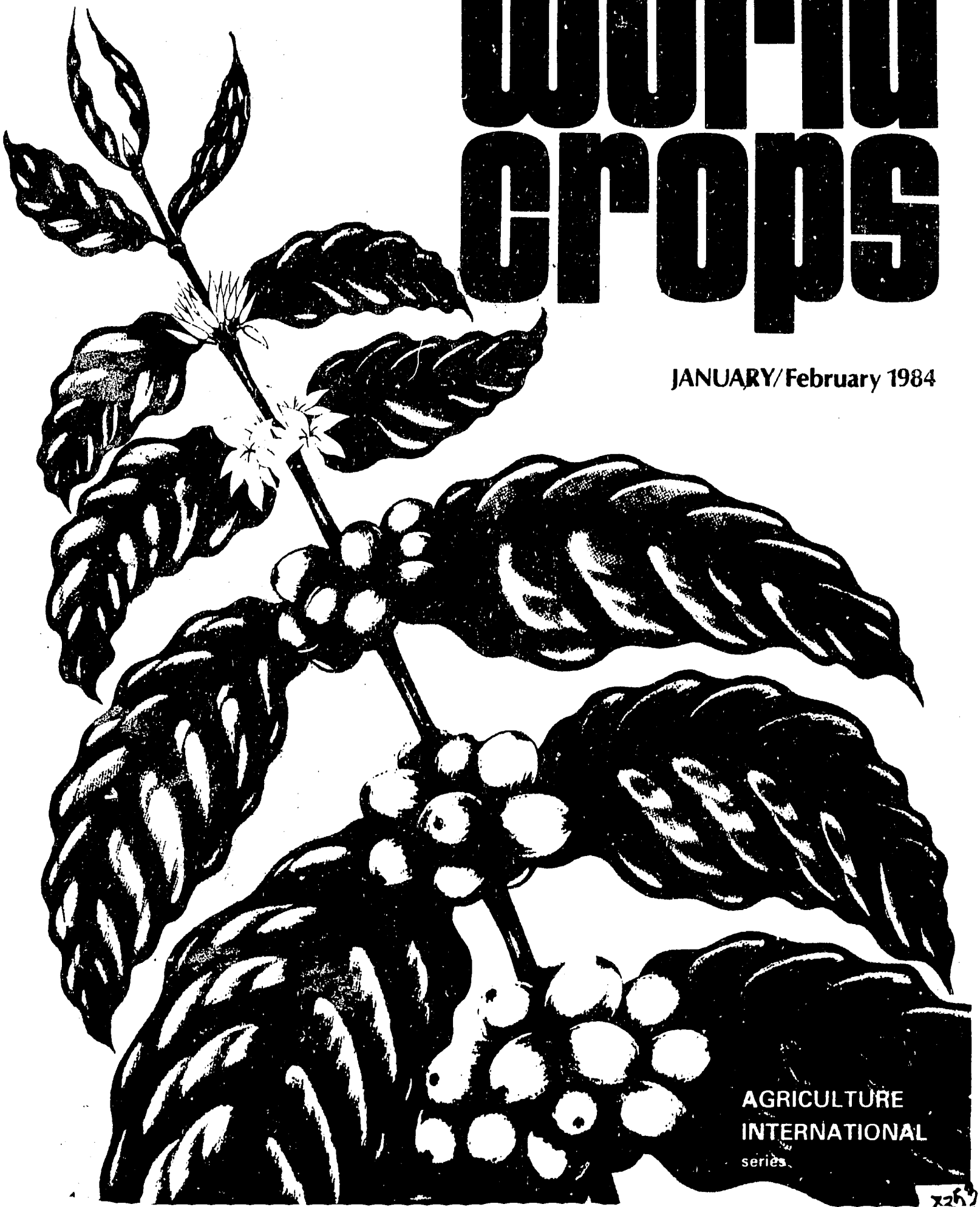
JANUARY/February 1984



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MEETING the demand for increased efficiency in water management requires the utilisation of the latest water-related technology. Superabsorbents represent one such step forward: an innovation that can be readily applied to increase plant survival, improve handling, conserve water, promote growth and reduce maintenance.

Superabsorbents, as soil amendments, are capable of absorbing hundreds and sometimes thousands of times their own weight in fluids. Individual superabsorbent particles can be considered as extremely efficient sponges which are insoluble and do not alter the nature of the moisture which is absorbed.

To gain an understanding of how these particles act to absorb moisture so efficiently consider a simplified molecule of the material (fig 1). Each particle or molecule can be thought of as having two main 'parellel' groups of atoms which are periodically joined by connecting cross-links like the rungs of a ladder.

When water comes into contact with a superabsorbent particle an electrical repulsion takes place causing the main branches of the molecule to repel each other as do the like poles of a magnet. When this happens water is drawn between the two branches resulting in a rapid swelling of each particle (fig 2) and at maximum capacity each particle will expand to over 30 times its original volume. As the water is extracted by the capillary action of the plant roots or evaporation occurs, the material shrinks back to its unswollen state. When water is added again the material re-swells absorbing the water as previously described.

The use of superabsorbents can increase significantly both plant survival and production rates especially in areas with irregular rainfall patterns of dry sandy soils as well as in reforestation projects and conventional cereal and forage production regimes.

This article describes what superabsorbents are and how they can be utilised as a tool to improved water management, to conserve precious water resources and to promote optimal plant growth, with reference to one particular commercial product.

Superabsorbents improve plant survival

Alasdair Barcroft

THE ABSORPTION CAPACITY of superabsorbents, like many other absorbent materials, is affected by salinity, pH, conductivity and other variables that inhibit expansion. It is not uncommon for a superabsorbent with an absorption capacity of 800 times its weight in pure water to absorb only 300 times its weight in actual use because of such variables.

The pH of the absorbed water should not present too much of a problem in most plant related applications since the pH of the growing environment would normally be within the ideal range (pH 6–9) for optimum absorption.

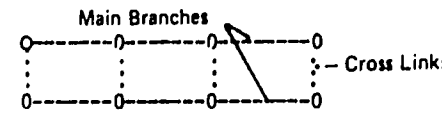
'Terra-Sorb' is the registered trade mark of one such superabsorbent manufactured by Industrial Services International Inc in the USA*. Terra-Sorb remains effective in the growing environment from a period of about six months to several years. After biodegradation occurs what remains of the material functions as a soil amendment, improving aeration and other soil characteristics. Interestingly enough the material which remains after biodegradation occurs is very similar to a soil amendment product marketed by Monsanto in the 1950s called 'Krilium'.

*Circle 2 on Enquiry Service for Information

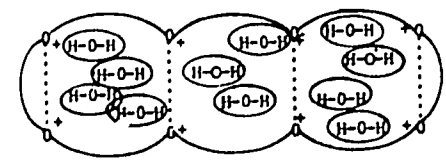
Most plants are watered on a schedule or when signs of wilting appear and such methods do not always ensure that the plant has adequate water or that needed for optimum, uniform growth. Normally by the time a plant shows signs that it needs water it has long since stopped growing. The use of superabsorbents, such as Terra-Sorb, allows the plant to obtain water as needed for optimum, uniform growth and there is little slow-down due to too much or too little water.

Oxygen depletion or carbon dioxide build-up in the plant root zone is harmful and potentially fatal to plants. When particles of a superabsorbent, such as Terra-Sorb, are present in the growing media, they will, upon absorbing water, expand to many times their original volume (fig 3).

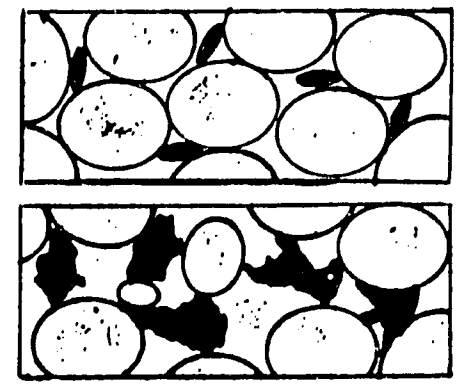
This expansion opens and exercises the growing media by forcing soil particles apart thus increasing aeration and improving drainage. Once these particles reach their maximum absorption point excess water flows freely over and around the particles as



1 Each molecule has in its structure two main parallel groups of atoms, periodically joined by connecting links



2 Water molecules: H – O – H. + Like polarity particles repel but are prevented from expanding too far by the cross links



3 As Terra-Sorb swells it forces soil particles apart, opening passages for air and at the same time improving moisture availability

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it would over a saturated sponge. 'Plugging' of the soil is not therefore a problem in the utilisation of superabsorbents of this type. The combination of good water availability and good aeration promotes faster growth and minimises the danger of root rot.

One of the major advantages of utilising a Terra-Sorb type of superabsorbent is its ability to make use of gravitational water. This is the water which moves freely through soil due to gravitational forces and is not always available to the plant because of its often rapid passage downwards. When superabsorbents are mixed with the growing media much of the gravitational water is held in a form that can be readily extracted by the plant root.

The concept of utilising moisture-retaining soil amendments is certainly not new, eg Monsanto's Krilium, and indeed such amendments as peat moss, vermiculite, urea formaldehyde materials (ureaforms) and other materials are widely used.

However these materials do not have the swelling or absorption characteristics of superabsorbents. For example, Hygromull TM, a ureaform amendment, absorbs about 30 times its weight of water whilst Terra-Sorb absorbs hundreds of times its weight in plant available water. Absorbents such as Hygromull TM, while having a low absorbency rate, have a relatively long and effective life in the soil environment. The use of a superabsorbent such as Terra-Sorb in conjunction with a material like Hygromull TM could be beneficial in areas of high moisture stress.

The practical uses of superabsorbents are wide ranging but essentially there are four basic ways of utilising Terra-Sorb superabsorbents:

1. Adding to growing media in a dry form.
2. Broadcasting over surfaces prior to planting or seeding.
3. As a gel dip when combined with water.
4. As a seed coating (Terra-Sorb 200G).

Examples of typical applications follows.

Transplanting

For large trees and shrubs/bushes, Terra-Sorb is sprinkled evenly into a hole prior to setting the plant or is mixed into the backfill. Smaller plants may be transplanted and shipped in a gel slurry consisting of Terra-Sorb and water. Tests by the University of Kentucky, in the USA, showed a 298% increase in plant survival rate through using Terra-Sorb in transplanting.

Terra-Sorb used in hydromulching at 75kg/ha

Amending Media

Superabsorbent particles of Terra-Sorb are simply mixed into the growing media to improve moisture retention. This application is ideally suited for potted plants, bedding flats and other containerised applications. Watering frequency requirements can often be reduced by as much as 50%.

The pepper plants grown in media amended with Terra-Sorb showed a significant increase in both plant height, stem structure and lead size compared to a control. A leading Florida based foliage plant grower has found that using Terra-Sorb has not only cut down his watering frequency requirement by as much as 50% but it has also reduced the finishing time of some crops by as much as 25%.

Gel Seeding

Terra-Sorb can be mixed with water and pregerminated seeds for gel seeding applications. The gel acts to protect the seed and emerging plants and provides a readily available plant moisture source.

Hydromulching

In hydromulching or hydroseeding applications? (of?) the superabsorbent is mixed with the mulch, water, seed and other additives to promote and speed germination and, at certain application rates (eg over 75lb/acre), act as a soil binder or tacker. This can reduce erosion due to both wind and water.

Broadcasting

Terra-Sorb superabsorbent particles can be broadcast over an area prior to seeding to enhance moisture retention, promote emergence and increase germination by providing the seed with a 'moisture reservoir'. Terra-Sorb has an immediate application to sod farmers whereby it is broadcast prior to laying seed to

Roots of an oak tree seedling that was dipped in Terra Sorb. Particles of plant-available moisture cling to the roots

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minimise transplant shock and to promote the rapid establishment of a luxurious green cover.

Mr Willis Branch, a tobacco grower in North Carolina, used Terra-Sorb in its dry form at a rate of 3lb/acre when bedding tobacco. The material was applied with a fertilizer applicator and dispersed into the soil when the beds were formed.l Several beds were not treated, as a control, and it was found that average leaf length in the treated beds was 35–36in compared to the control group average of 24–26in, with no apparent loss of quality in the leaf.

Bare root applications

Plant roots can be dipped or sprayed with a Terra-Sorb water slurry to provide essential moisture during shipping and handling. In addition to providing moisture, a reduction in shipping weight and hence cost is achieved since peat, clay or any other material is no longer required.

A leading Forestry Product Company in the USA has been using Terra-Sorb gel coating for two years in its packing/shipping operation for seedlings, with considerable success.

A leading rose grower in the USA saves US 7 cents for each plant shipped, by using Terra-Sorb, because of the reduced weight. The approximate cost of treatment is US 0.25 cents per plant.

Citrus and fruit tree industry

Terra-Sorb superabsorbents are being used to treat resets in the citrus industry to increase survival rates through a reduction in transplant shock and thus minimise reset losses as well as reducing watering requirements. It is estimated that in the USA every time it is necessary to water a citrus reset it costs the grower about US 40 cents but because the application on Terra-Sorb allows the soil to retain more water the watering frequency can be reduced and hence substantial savings realised.

A specially modified form of Terra-Sorb has been developed specifically for seed coating applications. Moisture absorbing particles of Terra-Sorb 200G expand as they draw moisture from the humid air or from liquid water. In expanding they form a gel 'fuzz' at the seed surface and moisture held by the gel softens seed tissues, promoting rapid germination. Plants grow faster because moisture is readily available to the seedling.

A major consideration in the development of Terra-Sorb 200G was to provide a moisture retaining seed coating which would be readily acceptable to traditional farmers.

Terra-Sorb 200G is a powder that is applied by simply mixing it with dry seed in the ratio of approximately one pound per 50 to 100lb of dry seed. It is ideal for seeder/hopper box application and as Terra Sorb 200 G contains graphite it is not only non-abrasive but also acts so as to lubricate the planting equipment, thereby maximising planting efficiency.

Tests conducted in the USA using Terra-Sorb 200G with wheat, oats, beans, soyabean and other crops have shown significant yield improvements and increases in crop values per acre of up to 15%. Average yield increases of 7 bushels per acre have been reported and the yield of soyabean has been improved by as much as 26%. An increase in germination of over 50% was reported by the US Soil Conservation Service in New Mexico in relation to certain grasses. Comparisons of plant height showed that those plants treated with Terra-Sorb 200G had an average height of 4–5in whereas the maximum height of the untreated plants was only 2in.

The potential for utilising Terra-Sorb 200G in, for example, the dry seeding of rice, one of the world's most economically important crops, is an as yet untapped area.

Cost is always a major factor in any agricultural, horticultural or forestry project and obviously the addition of any material to standard inputs such as fertilizers and agrochemicals will increase the production costs. However this additional cost should be viewed in the light of the potential benefits to the plant tree or crop which can include:

1. INCREASED: survival; rate of growth; germination; yield; shelf life; efficiency of water use.
2. REDUCED: labour costs; transplant shock; crop losses; crop growing time.

Typical costs for the application of Terra-Sorb superabsorbents, in a variety of uses, are:

i less than US$10 to treat a cubic yard of media which is equivalent to US6 cents per gal container
ii US4 cents to treat an 8 in hanging basket
iii US 6 cents to treat a 72 cell bedding flat
iv as a gel dip 50 seedlings can be treated for US 1 cent
v in sodding or hydromulching the cost is US 0.8 cent per sq ft
vi in transplanting a plant with a 1 foot root ball can be treated for US 40 cents
vii Fifty pounds of seed can be treated with Terra-Sorb 200G for about US 4 dollars.

Studies by universities in the USA such as Auburn University; the University of Oklahoma; the University of Georgia; and the Virginia Polytechnic Institute have confirmed that the addition of Terra-Sorb can reduce water stress; increase nutrient retention due to reduced leaching; replace peat moss as a moisture holding material; increase germination and in other ways improve the growing environment.

Most importantly Terra-Sorb superabsorbents are becoming an important tool in improved water management for farmers, foresters, nurserymen, landscapers and others involved in the 'green' industry. Terra-Sorb products should play an ever important role in assisting the increased production of food and improving the economics of plant production and installation throughout the world.

The US Forestry Service and independent foresters are now using Terra-Sorb products to treat over 400 million young trees per annum and the US Department of Agriculture (USDA) are predicting that the amount of superabsorbents used will exceed 100 million pounds per annum within the next few years.

In summary, in the words of Sara Groves, a horticulturalist at the Georgia Institute of Technology, USA, 'Having Terra-Sorb is like having a built-in baby sitter for our horticultural projects. We have found that newly planted seed flats, seed beds, transplanted flowers and shrubs and all growing plants are well protected with Terra-Sorb. In additiion Terra-Sorb reduced labour inputs and saves production costs'.

The potential applications for superabsorbents, in traditional agricultural, horticultural and forestry regimes as well as in the establishment of new plantation crops such as oil palm, rubber, cocoa, tea, etc, from nursery seedlings, is enormous and the benefits from utilising superabsorbents could be of great economic significance to an individual, a company or indeed a country.

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Christmas Trees

A MAGAZINE OF PLANTATION MANAGEMENT FOR CHRISTMAS TREE GROWERS

January 1982

8 Years From Now...Merry Christmas for Millions of Families

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TRANSPLANT SURVIVAL IMPROVED

By T.E. "Ted" Whitmore

620 Clinton Street, Kalamazoo, MI. 49001-Phone 616/385-4606

Transplant survival for Christmas trees and other forest trees will be much better in the future because of some new technology. A new water absorbing material used as a root dip is dramatically increasing survival and improving early growth on some Wisconsin, Michigan and Pennsylvania plantations.

The material, LIQUA-GEL® , absorbs 800 to 1,000 times its own weight in water, forming a mass of gel like particles. Used as a root dip the LIQUA-GEL slurry clings to roots, protecting them while they are out of the ground, then functions as a super sponge in the soil - giving up its moisture as the plant needs it, then reswelling when moisture is available to continue the process. It will remain effective in the ground through most, if not all of the first season.

Close-up of pine seedling roots after being dipped in Liqui-Gel slurry.

Pine seedling with roots dipped and ready for planting.

LIQUA-GEL is a modification of the starch graft polymers invented by the U.S. Department of Agriculture, North Central Regional Research Center, Peoria, Illinois and dubbed "Super Slurper." They have found wide acceptance in many applications both in and out of agriculture but especially in agriculture where they have been used to improve moisture retention and soil water relationships for plants.

This new modification not only has greater water holding capacity but also better retention on tree roots. The fine particles of gelled water will cling to the roots much better than earlier products which tend to be slippery and are more easily lost off.

The Wisconsin Christmas Tree Growers in their summer conference saw some dramatic results from using LIQUA-GEL when they toured the Campbell Tree and Land Company at Wautoma, Wisconsin. Ron Campbell had planted several thousand 2-2 Blackhill Spruce with and without LIQUA-GEL in April 1981. But, alas, the April showers failed and the planting went almost three weeks without additional moisture.

Survival was a short 50% where the LIQUA-GEL had not been used and a good 80% where it had been used. But that isn't the end of the story, probably one-half of the surviving non-treated trees will never become saleable because of the severe setback they suffered.

Ron is delighted with his results and says, "I won't plant anymore trees without it." But, he also points out some other benefits he found:

"The first thing the gel did was to protect the roots while we were transplanting. The bundles of trees dipped

Container grown Norway Spruce seedling with root ball dipped in Liqui-Gel.

in the gel could stay on the truck all day without drying out."

"Then, the weight of the gel on the roots helped to get them into the ground straighter. I'm sure we'll grow better trees because they'll have better roots."

It was a hot dry July 25th when the Wisconsin growers were at Ron's place and the cold beer went down real good. But, the trees that had been planted without LIQUA-GEL were wilting, while those planted with it were standing up pretty. The differences between the two groups of trees was quite dramatic.

Then in October, yet another advantage was noted when some of the better trees from both the treated and non-treated were dug and bare rooted. The treated trees had a distinctly better root system.

An interesting side note: Corn, soybeans and small grain seed that were coated with LIQUA-GEL before planting in 1981 generally emerged sooner than the untreated and developed a better root system, regardless of the moisture situation. The difference was noted from several states in conditions from dry stress to very wet.

Coating forest tree seed for direct seeding then becomes a distinct possibility, with the likelihood of improved trees in better stands.

THE COST? Ron Campbell says, "It cost me about 33/100 of a cent per tree to treat my 2-2 Blackhills Spruce: The LIQUA-GEL cost $6.60 per pound. One pound made 20 gallons of slurry and that was enough to treat about 2,000 trees. I figure I can treat about 10,000 pine seedlings with 20 gallons of slurry and I'm not even going to try to figure what that cost would be."

A logical question is frequently raised about the danger of reverse effect when the soil becomes excessively dry, 'will the gel in fact begin to draw moisture out of the plant?' Dr. Bill Doane of the USDA at Peoria says, "Yes, it might. But, by the time this would occur, the surrounding soil would have already dried out to the point that the tree without the gel would already have been dead anyway. The purpose for using the gel is to prolong the time a tree can go without supplemental water." Thus, the

Blackhills Spruce at Campbell Lane & Tree Company, 85 days after planting with Liqul-Gel. Note excellent candle growth.

question is really more academic than practical.

Use of the super slurper compounds is already wide spread in other plant growing industries:

--For bare root transplanting vegetable and tobacco crops and ornamentals

--For fluid drilling of pre-germinated vegetable seed

--For slurry dipping of container grown seedlings and other container or balled in burlap plants, bare root fruit and other trees

--Dry mixed into soils to catch and hold moisture on watering in potted plants; in backfill soils for planting trees and shrubs; on open soil before grass seeding or sodding, etc.

--in hydromulching

--etc., etc. additional use potentials can stretch your imagination.

Development work is currently underway on the best ways to incorporate insecticides, fungicides, nematicides, growth hormones, etc. into the slurry to help plants get a better start for a healthier and more profitable life.

ANTI-TRANSPIRANTS TOO

Another important tool for reducing tree losses due to moisture stress and to conserve limited soil moisture is through the use of anti-transpirants. Anti-transpirants are used extensively in horticultural applications for this purpose.

Anti-transpirants partially plug the stomata on plants, thereby reducing transpirational moisture losses. The plugging, while sufficient to reduce moisture losses, is not complete and does not interfer with respiration if properly applied.

The University of Maryland has recommended anti-transpirant usage for several years and according to Dr. F. R. Gouin, the practice has greatly reduced their transplant losses.

Maryland's recommendation is to dip the tops of the trees in an anti-transpirant solution containing 19 parts of water and 1 part VAPOR GARD®, as they are being prepared to go to the field.

Anti-transpirants can also be applied by thoroughly spraying the trees before they are removed from the seedbed using the same solution. Thorough coverage is the key to successfully using anti-transpirants.

® LIQUA-GEL and VAPOR GARD are registered tradenames of Miller Chemical & Fertilizer Corp., Hanover, Pennsylvania

Christmas Trees

A MAGAZINE OF PLANTATION MANAGEMENT FOR CHRISTMAS TREE GROWERS

Vol. 10 **No. 1**

Editor and Publisher: Charles "Chuck" Wright.
Advertising and Circulation: Alice C. Wright

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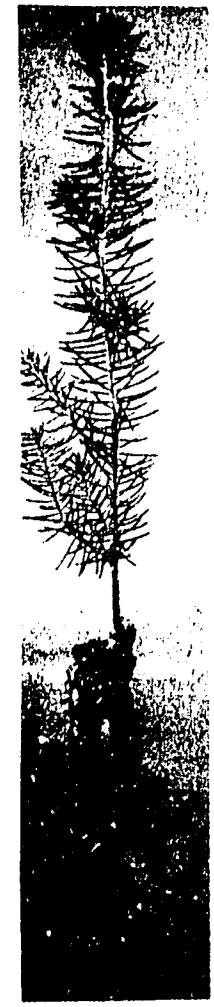

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October 16, 1980

Mr. James Quinn
Industrial Services International, Inc.
P.O. Box 10834
Bradenton, Florida 33507

Dear Mr. Quinn:

The transplant study with sugar maple on surface mined land turned out a little better than I had feared. The percent survival was as follows: control 6.7%; Terra-Sorb root dip (1 oz./gal) 20%. These figures represent an average of three replicates.

I realize these figures don't appear earth shattering but this was under the worst possible conditions. The plants were planted very late (May 27); the nursery stock was in rather poor condition; the site was a slope with fairly heavy cover; and, the area received approximately 0.3 inches of rain from May 20 to July 1.

I hope to put out a better controlled study next spring with the material.

Dr. Bob McNiel and I were discussing other projects for some of our surplus plant material. They will be generating quite a bit of container stock from other experiments in Lexington. We have an area here on the substation that has approximately 12 inches of soil over rock fill. The area should be droughty.

Bob and I are considering looking at the effects of Terra-sorb mixed into the backfill for establishing container plants on this area. We would probably measure survival, growth and root penetration.

We were wondering if your company might have some funds to help establish and support such a study. We have gone through some severe budget cuts, and the funds would be used to help support a technician for the summer. This

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technician would be used to help establish, maintain and collect data on research studies. We would be interested in any contribution that might be available from your company.

Thank you.

Sincerely,

David Hensley

David L. Hensley
Extension Specialist
in Horticulture

DLH/cj

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KENTUCKY

FORESTRY NEWS

Vol. VIII No. 1 Frankfort, Kentucky March 1982

NURSERY

By David Fisher

What's new? That is probably the most commonly asked question in the world. Probably the common answer is "I don't know. What's new with you?" That is not the answer you should be getting from the Division's nurserymen because there are quite a few new happenings in our Nursery Program. I would like to take this opportunity to acquaint you with just a few.

(1) New Species. We are continually examining the possibilities of introducing new species for our reforestation and wildlife programs. This year we have added Sawtooth Oak, Northern Red Oak, and Chinkapin. These species have been sown in rather small quantities in order to test the market. Other species which are under consideration are Pecan, Pin Oak, Paulownia, and Cypress. We are open to suggestions and comments.

(2) Improved Virginia Pine. This year for the first time all of the Virginia Pine seedlings grown can be classified as improved stock. Seed came from seed orchards set up by the U. S. Forest Service. Jim McConnell of that agency tells me that although the progeny tests from the orchards are only five years old, their form and early growth are fantastic. Next year we will be getting some more seed from this source. Within the next five years we should be getting improved seed from our own Virginia Pine orchards.

(3) Terra-sorb in Use at Morgan County Nursery. Terra-sorb is a gelatinized starch that holds several hundred times its own weight in water. We are using it as a moisture retention material on our seedling roots. We believe it is every bit as effective as clay and not nearly so messy.

There are several other new developments such as a new variety of Scotch Pine which we will be sowing this spring, more up-to-date information on mycorrhizal development on our seedlings, and herbicidal studies. More on these in the next issue.

Nolie "Red" Fletcher has now officially joined the 30-year club. Red has spent his entire tenure with the Division at Pennyrile State Nursery, and he played a major role in developing the nurseries at Kentucky Dam and Morgan County. I believe the Division owes a great deal of gratitude and appreciation to Red and others like him who have dedicated their entire working lives to the Division.

As of the first of March 1982, a total of 7.5 million seedlings had been sold state-wide. This figure breaks down into 2.7 million in district sales and 4.8 million in other sales. Seven and one-half million is about a million more than was sold last year at this time.

Agrosoke has big potential in tree growing

"Agrosoke" is a new product of great potential in growing tubed or tubbed trees — and for establishing trees on difficult sites or during dry seasons.

It is marketed by Naturefert Pty Ltd, and is attracting world-wide interest among agriculturalists, tree-croppers, foresters, and conservation tree planters.

"Agrosoke" is a polymeric soil stabiliser and water extender, and is perceived as a product of vast significance to all regions where tree establishment is inhibited by lack of water.

"Agrosoke" can literally put life back into barren, sandy soils.

Simply explained, the product is supplied in granules capable of absorbing 30 times their own volume of water.

When mixed with sand in ratio of approximately one part to 100 parts of sand and soaked with water, the granules expand and bind the earth. This creates a basis for the sand to be reconstituted into a loam capable of producing crops.

"Agrosoke" is also high economical. In fact, as a non degradable polymer-based material, the product need only be applied once prior to planting.

Its marketers claim the polymer:

- Improves the water retaining capability of desert sands or sandy soils and retards subsequent evaporation.
- Establishes strong, healthy trees in those areas formerly considered to be unsuitable for economic tree establishment.
- Improves soil structure and aeration and prevents mud accumulation.
- Makes possible more efficient use of irrigation water once a tree is established.
- Does not decompose in soil and has unlimited reabsorption capacity.
- Does not adversely affect trees or shrubs.
- Prevents erosion by the wind, through strong binding properties — even after the surface has dried out.

On contact with water the "Agrosoke" produces a viscous liquid, some of which forms a cap or 'crust' on sand surfaces. This helps to prevent wind erosion while still permitting subsequent water penetration.

Australians who have used "Agrosoke" see it as being of great potential benefit in:

- **Agroforestry** (especially in dry areas) where high-value, cloned trees are planted out as a "final crop", on wide spacing.
- **Conservation tree planting**, on sites that require trees for soil erosion control as the most economical method to apply.

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Roots of this plant were treated with "super slurper" and then dipped in water. The water is trapped and held in a gel around roots.

"Super Slurper" Gets Your Crop Moving Earlier

New compounds for coating seed and roots give your crop a fast start and may increase your yields with very little added expense.

By DEL DETERLING

"Super slurper" sounds like the name of a toy you'd buy for your youngster. It's no toy, however. It's one of a new family of seed and root coatings just now coming on the market, and it holds exciting possibilities for crop and forage producers.

These coatings are starch-based absorbents that, when they come into contact with water, set up like a gelatin salad does.

Research shows that by coating planting seed with this absorbent material, more seed germinate and do so faster.

The super slurper coating works this way: When a coated seed is exposed to moisture, the coating swells like a balloon and forms a gel-like cocoon around the seed. This then helps the seed germinate better, especially under dry conditions. Under certain conditions, these coatings can mean the difference between planting or not planting.

Applied to bare-rooted plants, the gel protects fragile roots and improves chances for the seedlings to survive. Manufacturers can add other materials to the coatings to protect the young plants from pests and diseases. Tiny amounts of plant food can even be included.

Although these products are still fairly new and supplies of them are limited, research and field tests give clues to what you can expect of them.

- Herb Partridge of Vernon, Tex., says cotton grown from gel-coated planting seed had 20% higher yields than cotton grown from untreated seed. For a cost of about 50 cents an acre for coating the seed, Partridge pocketed an extra $50 of income per acre.
- Elko Palaniuk, Jr., of Belfield, N. Dak., harvested 663 pounds of navy beans per acre from a plot planted with uncoated seed. He averaged nearly 1,500 pounds from seed treated with a super-absorbent coating.
- Willis Branch of Lumberton, N.C., cut his replanting costs in half by dipping tobacco plants in a gel coating. He says treated plants also grew off faster.
- In Arkansas, Dale Behmer, president of American Ag & Bio-Tech, Inc., reports up to 25% better stands from coated soybeans interseeded in drouth-stressed soils. In his best test field, yields were up by 30%—an increase of 12 bushels per acre.
- Seed coatings also are helping producers get better stands from ryegrass seeded by air, and from soybeans or sorghum planted in standing wheat.

"Use of coatings is an obvious method of increasing crop yields on the same amount of land," declares Roger Eisenhauer, industrial coordinator at USDA's Northern Regional Research Center, Peoria, Ill. "And the cost is so reasonable—generally less than $3 an acre."

Truck crop farmers long have been using coatings to equalize size of small, irregularly shaped vegetable seed for even planting. Many firms also sell coated alfalfa seed. This protects the bacteria put on seed to help the legume form nitrogen-producing nodules.

But new types of seed and root coatings really excite the imagination.

Super slurper, developed by USDA researchers at Peoria, is a good example. It is made from cornstarch and other chemicals and has the ability to absorb up to 5,000 times its weight in water and up to 100 times its weight in mineral solutions.

Super slurper was released in 1974 and there now are four major suppliers of the product: Henkel Corp., Minneapolis, Minn.; Grain Processing Corp., Muscatine, Iowa; Super Absorbent Co., Lumberton, N.C.; and Spenco Medical Corp., Waco, Tex. Some 50 more firms and individuals are licensed to use and distribute super slurper commercially.

Besides use in agriculture, super slurper is used to make firefighting aids and hygienic and medical pads; to seed grasses on mine spoil, along highways, and around construction sites; and for dozens of other purposes.

Earl Skinner of Henkel Corp. reports that about 50,000 pounds of

(Turn to 56P)

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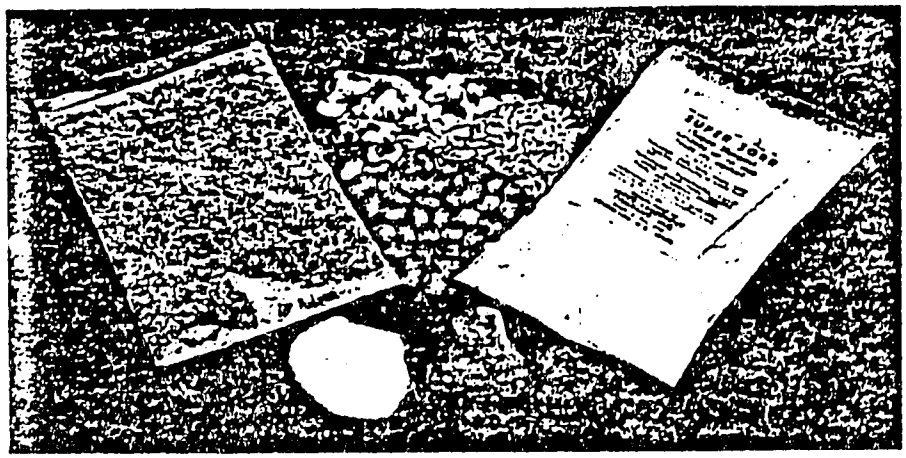


There are now four major suppliers of "super slurper." The material can be used on a wide range of crop seed.

soybean, wheat, sunflower, and pinto bean seed coated with the firm's SGP polymer were planted in 1980.

"We've also had good luck with corn, alfalfa, cotton, and guayule, a rubber-producing desert shrub," he says. "In every case, we've been able to get faster germination of seed—usually by several days. We've obtained a 10 to 15% better stand. In some cases, this may allow farmers to use lower planting rates."

Ed Kirkland, president of Super Absorbent Co. reports that farmers in his area have been getting 10 to 34% improvement in stand from coated soybean seed. He manufactures both a powder Super Sorb, and a flake, Magic Water Gel, that can be used to coat seed and roots of nursery, tobacco, and tomato plants.

Grain Processing Corp. sells its starch-based powder, Water-Lock, directly to producers of nursery stock and potting soils, and to a few seed companies.

Stasorb 372, a product of A. E. Staley Manufacturing Co., Decatur, Ill., has potential use for seed coatings. The compound is chemically different from super slurper but very similar in the way it works.

The search continues to find ways to use and apply the super coatings most efficiently. Some workers think it will be most convenient for seed companies and dealers to coat planting seed for farmers. But growers may be able to coat their own seed, using a tub, cement mixer, or ordinary seed treatment equipment. Elko Palaniuk is testing a planter-box treatment that appears to be very effective. Herb Partridge, a representative of Henkel Corp., reports success with an in-furrow treatment for planting closely spaced seed.

Dale Behmer of North Little Rock, Ark., hopes to introduce a system in 1981 that keys the use of coated seed to an interseeding program.

"By interseeding, I mean growing two crops on the same land during the same season," Behmer explains. "For example, coated seed can help us get an acceptable stand of soybeans broadcast planted in winter wheat when the grain is about knee high. These beans would be about 1 foot tall when wheat is ready to be harvested. The straw will serve as a mulch to conserve moisture and create shade to hold down weed growth.

"The grower should be able to avoid all cultural practices, except possibly some broadleaf weed control," Behmer continues. "He'll need no tillage at all, so his production costs should remain very low."

Behmer also reports good results from broadcast planting of grain sorghum in growing wheat. "It also should be possible to come back and plant wheat in growing soybeans before they are harvested," he adds.

"There's nothing magic about this," Behmer cautions. "Coated seed can help a farmer get a stand if his soils are stressed for moisture at planting time. But they won't save him unless he gets rainfall or irrigates during the growing season."

The idea of fluid drilling is even more revolutionary. Dr. James Motes, Extension horticulturist at Oklahoma State University, says fluid drilling makes it possible to plant pre-germinated seed that have been coated with a gel. The gel protects the tender emerging root and helps the plant establish itself more quickly. The technique can be especially valuable to vegetable producers.

Manufacturers expect to be able to add various chemicals to the coatings to protect seed against insects and diseases, change the pH around the seed, and to nourish it with plant food and trace elements.

For example, sorghum researchers are testing seed coated with iron on soils in which low iron availability kills sorghum or reduces grain yields. New Mexico scientists have improved plant stands by 12% by planting iron-coated seed, although they have not been able to increase yields. Oklahoma scientists agree that iron coatings do give sorghum seedlings a boost but say they play out too early to give season-long relief.

Work also continues on other types of coatings.

At the University of Kentucky, Dr. C. T. Dougherty is testing Celpril, a lime-based coating from Celanese Corp., on forage legume seed. The coating protects seed that have been inoculated with nitrogen-producing bacteria. "It gives pre-inoculated seed a longer shelf life and protects them during seeding," he says.

Several seed companies use Celpril or similar compounds to coat alfalfa seed. Roger Pirie of Germain's Seeds in Fresno, Calif., reports that over half of the alfalfa seed his company markets in irrigated areas of the West are coated.

"The coating makes it easier for farmers to handle the pre-inoculated seed," he says. "And where moisture is adequate, we are getting as good or better germination from coated seed as from uncoated seed."

But Northrup King spokesmen say they haven't been able to see much advantage from coated seed. "We think a grower will be ahead by taking the money that he would pay for the coating and planting more seed instead," says Winfield Johnson of NK's Fresno office.

Dr. William M. Doane, captain of the USDA research team, predicts that planting uses alone could eventually account for use of more than 100 million pounds a year of the super slurper. Add the potential increase in use of other types of coatings and it becomes obvious we've barely scratched the surface in finding ways to use these exciting materials. ■

Cellulose xanthate increases vegetable seed emergence

Very encouraging increases in emergence of small-seeded vegetables can be obtained if the soil is treated with cellulose xanthate shortly after drilling. This is the conclusion from the first year's field trials of the product, 'Vi-Grow'.

Vi-Grow was first reported last year by Dr Ron Page of the UK's National Vegetable Research Station (NVRS).

Dr Page found that cellulose xanthate was substantially the most effective for stopping capping, and thereby increasing emergence.

In addition to its anti-capping ability cellulose xanthate can:

1. Enable seed rates to be reduced.
2. Avoid transplanting and allow direct drilling in the open.
3. Enable contracts to be met with greater certainty.
4. Give stronger earlier growth and greater regularity.
5. Bind soil against wind erosion.

THE FINE crumb structure of the seedbed is important in ensuring that a high percentage emergence of plants is obtained. This is particularly so with small-seeded vegetables and flowers. In many soils the crumbs produced by tillage to form the seedbed can be broken down by rain. The soil then slumps to form a smooth, dense, surface layer.

In the worst case, under the influence of sun and wind, the soil dries and forms a hard crust or cap which can physically prevent the seedling from emerging.

Under less severe conditions, where the soil remains moist, the seedling is not prevented from breaking through the crust but the loss of the crumb structure reduces aeration and porosity. This can slow the growth of the seedling. It was shown that when Vi-Grow was sprayed on to a soil with a good crumb structure this structure was maintained even during heavy rain.

The binding effect was retained because the soluble cellulose xanthate rapidly decomposed to insoluble cellulose when in contact with the soil. Cellulose is, of course, a naturally occurring polymer — the building block of all plants.

Anti-capping trials

To follow up the early results, Courtaulds, the suppliers of Vi-Grow, organised a wide range of field trials in close co-operation with NVRS and Agricultural Development Advisory Service (ADAS).

In all cases the trials were on land prone to capping (clay/silt soils). In most cases strips comprising 1 acre of the crop area were treated with Vi-Grow and compared to the remainder of the area.

Vi-Grow was supplied as a liquid concentrate in 25 litre plastic containers. The concentrate was diluted with water to 2% cellulose for spraying, and applied at a rate of 25kg cellulose/ha. Although the spray liquor is more viscous than water very few application difficulties were experienced using fan or hollow cone nozzles in conventional sprayers.

The treatment was applied either as bands or overall, depending on crop spacing and availability of band sprayers. Spraying took place shortly after drilling either before or after application of pre-emergence herbicides. After germination, emergence counts were undertaken by either ADAS, NVRS or Courtaulds as was convenient.

Good results—despite the weather!

The emergence counts showed that the Vi-Grow treatment amply fulfilled the promise indicated by the results of the work at NVRS—in a few cases improvements of over 80% were obtained.

The trials were very representative of the beneficial effect that could be obtained since the treatment was applied to successive drillings of lettuce and salad onions in the period May to June.

The variation in the extent to which the emergence was improved by Vi-Grow almost certainly reflects the prevailing weather conditions in the crucial period between drilling and emergence.

A similar picture emerged from those trials monitored by Courtaulds and/or Dr Page. In both sets of trials very significant improvements in emergence were usually obtained when the untreated crop showed poor emergence due to the weather.

A very good example of this was found at Chicory Crops Ltd where a 94% improvement was obtained.

Many of the large improvements were obtained in the early part of the year when the weather was very dry. It seems probable that Vi-Grow improves the water holding ability of the soil.

Unexpected benefits

It was also frequently noted that the plants in the treated areas emerged earlier and were stronger and more regular than those in the untreated area. This was borne out by successive emergence counts taken on lettuce.

Emergence in the treated areas could be complete up to five days earlier than in the untreated areas and thus lead to earlier harvesting.

Control of wind erosion

Wind erosion can result in loss of seed or seedlings at an early stage, and later can cause damage to established plants. Loss of organic soil itself is serious. Since Vi-Grow is an effective soil binder it was felt that it may also be effective at protecting crops against wind erosion.

The initial trials suggest that this is so when an application rate of 30–50kg/ha is used.

Circle 86 on Enquiry Service for information

Gel-Dipping Georgia Pepper Transplants

By W. BRADFORD JOHNSON

THE roots of Georgia-grown pepper plants of the *Emerald Giant* variety were dipped in a gel before shipment to New Jersey last spring. The dip was made by mixing ½ ounce of gel per gallon of water.

The dipped transplants, with an equal number of undipped plants, were shipped in a truck to the Rutgers Research and Development Center in Bridgeton, N.J. The objective was to determine if the gel would have an effect on plant survival in the field and on subsequent growth.

The plants were set 1 foot apart in rows spaced 5 feet apart. There were 25 plants per plot in four replicates of dipped and undipped plants. Starter solution was used when the plants were set.

Soon after the plants had become established it was possible to see that the dipped plants were slightly shorter but more branched than the undipped ones. Survival was 100% for both lots of plants. It was decided to grow the plants to harvest to see if the difference in growth would affect yield.

The plots were given routine care and irrigated as needed. When the crown set reached marketable size, all plots were harvested and records taken of the weight and number of fruits from eight plants in each plot. The data were analyzed and are presented in Table 1 and 2 below.

A later harvest was made, but no significant difference in weight or number of fruits was found. Growing conditions late in the season were not favorable.

Table 1: Weight of fruits in the first harvest from Emerald Giant pepper plants.

	Weight in pounds
Dipped	11.20
Undipped	8.47

Table 2: Number of fruits in the first harvest from Emerald Giant pepper plants.

	Number of fruits
Dipped	34.75
Undipped	23.75

CONCLUSIONS

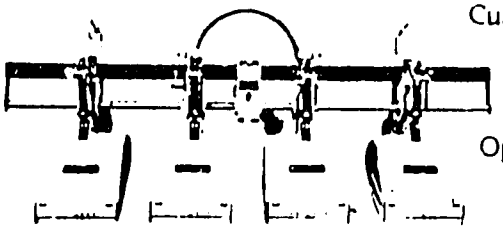
The increased branching of the dipped plants seemed to give rise to enough additional blossoms to result in a significantly greater number of fruits.

If a root dip can increase the number of first harvested fruits, it would be at a time when the market price is frequently higher. This could mean increased returns to the grower.

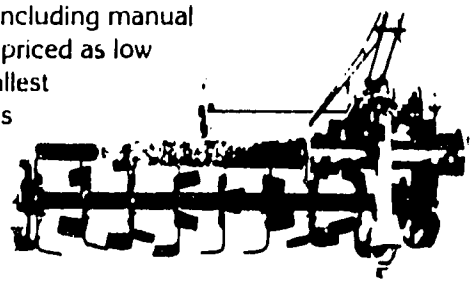
Johnson is extension vegetable specialist, Cook College, Rutgers University, New Brunswick, NJ 08903. This work was done in cooperation with Dr. Casimir Jaworski, Georgia Coastal Plains Experiment Station, Tifton, Ga 31793.

THE SHIFT IS ON TO BEFCO

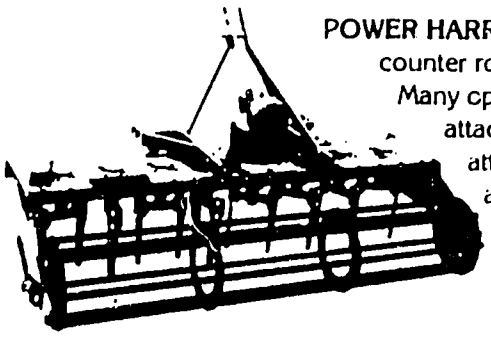
INTERROW CULTIVATOR: 5 Series Power driven high clearance cultivators. Cultivator heads from 5 to 36". Clearance from 16 to 34". Tool bar with up to 176". Each head spring loaded. Options, fertilizer hoppers and ridgers. Priced much lower than competition.



ROTARY TILLERS: 7 Series including manual and automatic side-shift units priced as low as $1000 list price for the smallest units. Machine and knife prices much lower than other well known brands.



POWER HARROWS: Very heavy duty units, counter rotating tines, from 44" to 30'. Many options available such as quick attach BED SHAPERS, front disc attachment, tow hitches for pull and lift type planters and drills, etc. Priced much lower than other well known brands.



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HAVE YOU READ . . .

Potato Late Blight — Epidemiology, a 13-minute color film produced by the New York State College of Agriculture and Life Sciences at Cornell University, describes the influences of environment, host, pathogen, and cultural practices on epidemiology. Potato late blight is used to illustrate epidemic development, and disease control procedures are emphasized in scenes of commercial potato production.

For more information, contact the Cornell Audio-Visual Resource Center, 8 Research Park, Ithaca, NY 14850.

Gel Planting — A Rising Tide

'Gel seeding' or 'fluid drilling' of pre-germinated vegetable seed is now an established practice. But it is only the beginning of a tide of uses for the water gelling or 'Super Slurper' products in the overall planting picture.

Gel transplanting, gel overlays for precision planted and other dry seeding, gel seed coatings, gel modified soils, gel packing of bare root plants, etc. are coming on fast. It's not only in vegetable production but also in row crops and small grains, pastures and grasslands, forestry, greenhouses and ornamental horticulture.

"Anyone equipped to gel seed pre-germinated vegetable seed is also equipped to gel seed non-germianted seed," says Dr. James E. Motes, Horticulture Department, Oklahoma State University. "I do all my vegetable seeding in gels, pre-germinated or not."

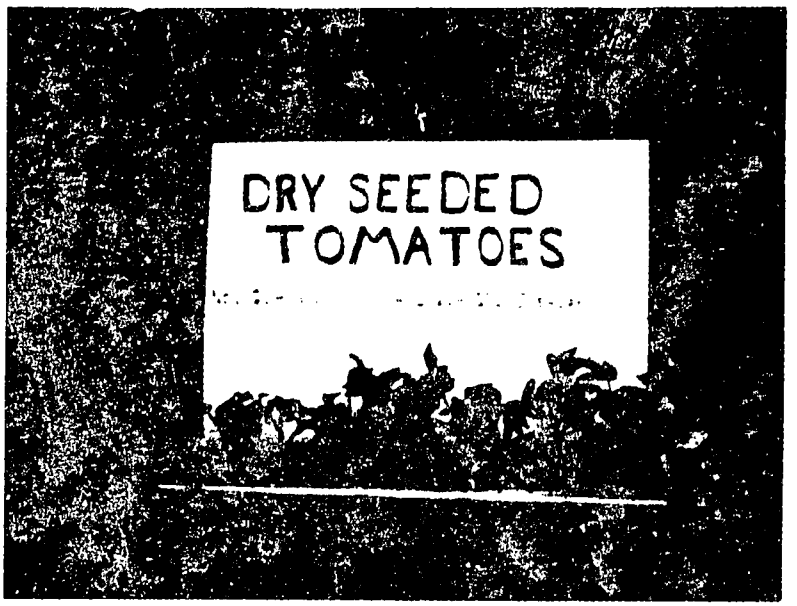
Dr. Motes began working with gel seeding at Michigan State University with Dr. Hugh Price and has continued developing gel planting techniques since moving to Oklahoma. He is, like Dr. Price, one of the leading authorities on the subject in the United States.

Gel Transplanting Is Bigger

Already, gel transplanting is more widely practiced and growing faster than gel seeding. Tobacco seedlings, all kinds of vegetable transplants, fruit trees and vines, forest trees and ornamental nursery stock are all being gel transplanted.

No special equipment is needed for gel transplanting, just a container in which to mix a gel slurry and dip the plants. A gelled water slurry is prepared to a consistency that will cling to plant roots. Then, bundles of plants or individual plants are root dipped into the slurry and moved on out for transplanting.

"Every bare root transplant should have gel on its roots," says Ted Whitmore of Miller Chemical & Fertilizer Corp., who has spearheaded development of their water gelling product Liqua-Gel tm.



Dry seeded tomatoes are shown planted both with and without a gel overlay. The advanced growth resulting from the gel overlay can be observed.

"The gel protects the roots from drying while they are out of the ground, then puts extra moisture holding capacity into the soil, right around the roots where it is needed. In the soil the gel particles will continue to give and take moisture for more than a year before bio-degrading.

"In dry soils even the root balls of container grown plants like Speedlings® are being dipped with excellent results. It is a bit aggravating but not as aggravating as re-planting.

Ron Campbell in Wisconsin says, "After root dipping my transplants in Liqua-Gel slurry, I can leave them on an open truck all day without the roots drying out. This alone makes the gel worth far more than the little extra cost and effort. $6.60 worth of gel will make enough slurry to dip 8 to 12,000 seedlings so the cost is really nothing."

"The gel in the soil also gave me a tremendous increase in survival when we failed to get rain for almost three weeks after planting," Mr. Campbell adds.

Gel Seed Coating

Coating the water absorbent product onto seed is another planting tool that is taking off like a great big bird. All kinds of seed from small vegetable seed to large farm seeds are being coated, first with a tackifying material or a regular liquid seed coating (generally in soybean or cottonseed oil) then the dry gel powder is added as the seed are being tumbled. Water carriers are no good.

Originally the gel coatings were expected to improve seed germination and crop stands when plantings were made into marginal moisture situations. Available moisture would be absorbed by the gel particles and held tightly against the seed to get them imbibed and growing. It works well.

"In our Liqua-Gel testing we not only got a better stand, but earlier germination was an obvious bonus with most of the seed tested. Many crops were up 2 to 3 days earlier, some even earlier," Ted Whitmore reports.

Reprinted From The Great Lakes Vegetable Growers News — March, 1982

"What would happen in wet soils was the next obvious question: We got our answer in several areas in 1981. After planting our seed treated with Liqua-Gel the rains came and we had adequate to excessive moisture in the same fields with both treated and non-treated seed planted side by side. The treated seed still came up earlier, the seedlings were taller and more robust and had better root development. The only thing we didn't get was a better stand, they were equally good.

"The gel is definitely not a problem in wet soils, if anything it is an advantage," Ted adds.

Gel Overlays on Dry Seed

"So why not gelled water overlays for dry seed? The effect of extruding a stream of gelled water directly onto seed before they are covered in precision planting should be the same as fluid drilling non-germinated seed.

"It has worked out exactly that way," Mr. Whitmore continues. "Conditions are just right for the seed and the results are spectacular; quicker germination and stronger plants get off to a better start."

"No special equipment is necessary for applying gel overlays, like the squeeze pumps that are essential for pre-germinated seed. A clean tank, a PTO pump and connecting hoses — or even a gravity feed system and you're in business. A squeeze pump is nice but even a centrifugal will do.

Not Without Problems

Like anything else the water gelling products have some problems. But fortunately, not many have appeared or been too serious:

1) Dehydration by minerals in water: As the ion mix and concentration varies in waters, so does the amount of gel it takes to achieve a desired slurry density. This means that each source of water is a variable and only guide line recommendations can be given on use rates.

For instance, 1 lb. of Liqua-Gel tm or 3 lbs. of Terra-Sorb® in 30 gallons of most waters will make a pretty good slurry for fluid drilling or overlaying. But some waters will require more gelling material and others less to achieve a working density.

2) Dehydration by fertilizers and other chemicals: As nutrients, hormones, and other additives are introduced into the slurries, more gelling material is often needed to maintain a working density.

3) The inorganic colloidal gels, such as Laponite®, vary in gel density as they are stirred or jostled during field uses, which tends to give somewhat variable application rates. This is not a problem with the starch-graft-polymers.

Research and Development work is ongoing to overcome these problems as well as to improve existing uses and find new ones.

Occasionally the question is raised, 'If soil conditions become excessively dry, will these materials reverse and actually take water away from plant roots?' Dr. William Doane of the USDA at Peoria, Illinois, lays that one to rest, "Not on a practical basis. The purpose of the 'super slurper' is to hold large amounts of water available to plant roots. By the time the moisture is depleted to the 3 or 4 percent level where reversal might occur, the plants would have long since been dead without the 'super slurper.'

A Tide Just Beginning

The use of the starch graft polymers is a tide of the immediate future which is just now gathering momentum. They are economical, the benefits are good and the problems minimal; a hard combination to beat.

Research and development projects are finding more and more of the answers on how to best use the gels and gelling products. Several commercial companies are diligently seeking and finding both answers and new uses for their products.

In addition to the continuing work by Drs. Hugh Price and Jim Motes mentioned earlier, a number of other University workers are grinding out more and more answers. Workers like:

Dr. Dan Cantliffe at the University of Florida, working on potting soils and growth stimulants for use with gels.

Dr. Herb Bryan, Homestead, Florida, working with gels in various planting systems and techniques.

Dr. Richard Arteca at Penn State, working with growth stimulants and anti-transpirants with and without the gelling compounds.

Just to name a few. There are many more researchers in Universities and the USDA doing excellent work as well as a number of consultants and private workers.

Thanks to the USDA

But, we must say thanks to the U.S. Department of Agriculture team at the North Central Regional Research Center, Peoria, Illinois, who originally discovered the starch-graft-polymers (SGP's) and who continue to monitor their development.

Dr. William M. Doane and his team originally named their product 'Super Slurper' and have helped introduce them into many industrial as well as agricultural uses. What their final destiny might be is a story now unfolding. One thing is certain, they will be very widely used and very important tools in agriculture. □

Terra–Sorb, Protection for Bare Root Stock!

NURSERYMEN are well aware of the increasing demand by landscapers and local authorities for ample protection of bare root stock to prevent drying out during transportation and prior to planting. Research has confirmed that losses and reduced vigour can be due to drying out of the roots. Container plant producers and garden centres are all too conscious of the amount of water needed to keep container compost moist and how difficult it is to re-wet after drying out. Customers buying plants remain uncertain about how much water to apply, or how often, to ensure fast and certain re-establishment.

On production nurseries watering is the most important operation and often is the one causing greatest concern. The almost total swing to peat or peat/bark composts with slow-release fertilisers demands constant availability of water to promote optium growth. Nutrient uptake, root development and plant growth all depend on water and growers know it, but all too often irrigation equipment is less than 100 per cent efficient and dry plants result.

There have been additives around for some time that claim to improve water retention in the compost, and some proprietary brands have quick water-absorbing properties. British nurserymen, however, tend to shy away from anything that adds even part of a per cent to the cost of production unless there is proof that it adds to the yield or the asking price for the plant.

A new product recently introduced to the U.K. from America where it has been gaining steady support over the last three years is Terra-Sorb, a concentrated polymer capable of absorbing hundreds of times its weight in water very quickly and acting like an insoluble sponge that does not change the nature of the moisture it absorbs. It is a dry gelatine-like crystal which when added to a compost or growing medium holds moisture and releases it over an extended period. Expansion of the particles in contact with water opens up the compost structure; water extraction returns the Terra-Sorb to its unswollen state and increases the air spaces in the compost, it is claimed.

Technical data refers to its quick and easy dispersion in liquids; neutral pH; being unaffected by heat at 300 deg.F; capacity of reabsorption; and its claimed biodegradable non-toxic characteristics. Ideally, mixing should be with compost media in a relatively dry state. Terra-Sorb basically appears to have considerable potential and deserves trialling by the trade and experimental stations in the UK under UK conditions for the production, transportation and transplanting of nursery stock and young plants. Local conditions and techniques will affect the results, and inevitably the use of the material would incur change.

Principal uses in America are during shipping and handling of containers and bare root nursery stock. Treatment of bare roots with Terra-Sorb gel (one pound in 20 gallons of water) is said to be twice as effective as peat in terms of available moisture by weight of water. Forestry seedlings have been shown to benefit from gel treatment and one pound of Terra-Sorb will treat up to 10,000 seedlings.

Transplanting of all types of nursery stock is improved when ample water is available to the roots. Terra-Sorb at one ounce per foot of root-ball diameter sprinkled into the holes and puddled around the root zone with two or three ounces per cubic foot of backfill ensures increased moisture availability over an extended period at a cost of about 20-30p per tree. Nutrient leaching is claimed to be inhibited but only trials will tell.

Dipping of small plants, vegetable and bedding plant transplants in a Terra Sorb gel also increases water retention in the root zone, say the Americans. In landscaping the possibility of planting with the knowledge that Terra-Sorb treated plants can go up to three times as long as untreated plants without watering has led to its growing use as a standard application by convinced landscapers. Large-scale hydroseeding and hydromulching has been another American application, and where Terra-Sorb has been used in lawn seed dressing and pre-turfing application results are reported to be improved.

Other applications suggested include reduced frequency of watering of indoor plants and hanging baskets; in propagation; pre-planting treatment of flower beds and new lawns, and for potting-on in the greenhouse. Cost (at under £2 per pound) will partly determine the commercial future of Terra-Sorb in the U.K. and the user must weigh the product cost against the saving in labour for watering (and the saving of water itself) and possible stock losses through drought. Importers and distributors of Terra-Sorb are Martin-Golod Products Ltd., Maybury Gardens, Willesden High Road, London.

(GREAT BRITAIN)

1982
Sweet Pod

INTRODUCTION TO A NEW TECHNOLOGY

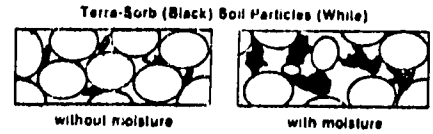
SUPER-ABSORBENTS SAVE TIME AND MONEY

Super-absorbents are a new group of wonder products that deserve the attention of gardeners and horticulturists in all parts of the world. These absorbents are capable of storing several times their weight in water as a gel, holding it available for plants and at the same time actually increasing soil aeration and improving drainage.

These sponge-like compounds originally were developed by the U.S.D.A. Northern Regional Research Center in Peoria, Illinois, and although they are now available in several different brand names, all actually are composed of a man-made acrylic compound chemically grafted to cereal grain sterches. These powders, which in their dry form may look something like slightly off-color dry milk or wheat germ depending on the product involved, can absorb from 200 to 5,300 times their own weight in water.

Thus far, most of these products are available only to nurserymen and other professionals, but they are marketing TERRA-SORB so it will be available to the homeowner through retail markets.

Water is fundamental to all plants. TERRA-SORB absorbs and stores plant available water, releasing it to the plant on demand. To gain an understanding of how these particles act to absorb moisture so efficiently, we can consider a simplified molecule of the material. Each particle or molecule can be



considered as having two main 'parallel' groups of atoms. These groups are periodically joined by connecting cross-links like the rungs of a ladder.

When water comes into contact with a super-absorbent an electrical repulsion takes place causing the main branches of the molecule to repel each other as the like poles of a magnet. When this happens, water is drawn between the branches resulting in a rapid swelling of each particle. TERRA-SORB remains effective through many swell-shrink cycles. In the growing environment the super-absorbent remains effective from a period of about six months to several years.

Oxygen depletion or carbon dioxide build-up in the plant root zone is harmful or fatal to a plant. When super-absorbent particles are present in the growing media, they will, upon absorbing water, expand to many times their original volume. This expansion opens, and exercises the growing media by forcing soil particles apart, INCREASING AERATION AND IMPROVING DRAINAGE. Once these particles reach their maximum absorption, excess water flows freely over and around the particles as it would flow over a saturated sponge. PLUGGING OF THE SOIL IS NOT, THEREFORE, A PROBLEM.

Continued on page 22

NEW TECHNOLOGY . . .

Continued from p. 11

The combination of ideal water availability combined with good aeration promotes faster growth and minimizes the danger of root rot!

GRAVITATIONAL WATER is water that freely moves through the soil due to the forces of gravity. This water cannot usually be used by the plant because it rapidly moves out of the soil.

CAPILLARY WATER is water that is held very loosely around the soil particles. The water is held by cohesion (attraction between like molecules). Most of this water is available to plants. Capillary water can be considered as being in the form of a thick film around the soil particles. The water moves to the point of highest tension (lowest pressure). The root hairs create a low pressure and are capable of drawing moisture until the attraction between the soil and the water molecules exceeds the attractive forces of the roots (permanent wilting point).

HYGROSCOPIC WATER is water held in the form of a very thin film around soil particles. It is not usually available to plants.

When super-absorbents are mixed into the growing medium, the material absorbs gravitational and capillary water. This water is held in a form that can be readily extracted by the plant root.

TERRA-SORB can be applied in a variety of ways, such as:

1. Distributed evenly in a hole prior to transplanting.
2. Mixed directly into the soil or other growing media.
3. Applied as a gel to plant roots.
4. Used as a media for gel seeding.
5. Used in hydroseeding applications.
6. Broadcast over an area to be seeded.
7. Applied as a seed coating.

For transplanting larger plants TERRA-SORB is sprinkled evenly into the hole prior to setting the plant. One to two ounces per foot of root ball diameter is recommended. The hole should then be filled and watered in as usual.

Media for bedding flats, potted plants and other applications can be treated with TERRA-SORB by mixing in the TERRA-SORB at a rate of about two pounds per cubic yard of media.

Smaller plants may be transplanted and shipped with a gel slurry consisting of TERRA-SORB and water. About four ounces of material should be added to five gallons of water to form a thin slurry that will adhere to the roots without totally covering them, to avoid cutting off aeration.

Continued on p. 24

Actual Size

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NEW TECHNOLOGY . . .

Continued from p. 22

Interior plantscapers are using super-absorbent-amended soil mixes to reduce their watering schedules on indoor plantings, and with a little bit of experimentation, a vacationing house plant enthusiast or patio gardener could have his vacation and still keep his peace of mind knowing his plants are all well watered. Indoors, plants grown in amended soil may need water as seldom as once a month, and wick-watered plants or those grown in self-watering planters will need water even less often. Either repot house plants with amended soil or mix some super-absorbent with water to form a loose gel and plant plugs of it directly in the pot. Plant roots are able to extract water directly from the gel, and rooted cuttings actually can be kept in super-absorbent gel alone. The roots act as a check valve and allow water to enter the root but not leave it. DO NOT TRY TO ROOT CUTTINGS in this manner, however, since in the absence of roots, the gel can pull water out of the plants. You can, however, grow unrooted cuttings in a soil amended with super-absorbents.

TERRA-SORB can be mixed with water and pregerminated seeds for gel seeding applications. Special planting machines plant the pregerminated seeds which are suspended in the gel mixture. The gel protects the seed and provides a source of moisture for the emerging plant.

TERRA-SORB can be broadcast over an area to be seeded to enhance moisture retention, promote emergence and increase germination by providing the seed with a 'moisture reservoir'.

These water absorbent polymers are compatible with all species of plants. They do not affect and are not affected by the pH of the soil or soilless growing medium, and, in their dry form, they can be stored indefinitely in a moisture-proof container.

For long-distance bare-root shipping the application of a TERRA-SORB gel to the roots of seedlings not only provides moisture, its use also reduces shipping costs.

Advantages that TERRA-SORB provide:

- Increased survival
- Increased rate of growth
- Increased shelf life
- Increased germination
- Increased efficiency of water use
  - Reduced labor costs
  - Reduced transplant shock
  - Reduced crop growing time
  - Reduced shipping costs

Obviously a product with all these characteristics could be put to an almost limitless number of uses in the garden. Explained in this article are only a few of the many uses for super-absorbents and scientists, horticulturists, landscape contractors and home gardeners will undoubtedly discover more as these products become better known.

NOTE: For further information on obtaining this super-absorbent, please see inside back cover. Commercial growers wishing further statistics on TERRA-SORB and its benefits in the large-scale growing and shipping, please write the Editor for full report.

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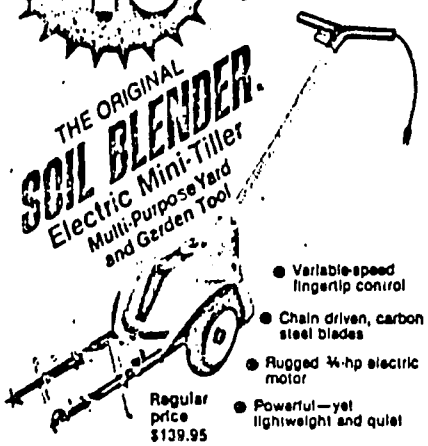

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A new tool for gardeners

SUPER SLURPER

By Dr. Jim A. Alston

Super Slurper is a water-loving (hydrophilic) compound of rising importance to gardeners.

The compound is a starch derivative, having synthetic polymers grafted to it. Chemically, it is identified as "hydrolyzed starch-polyacrylonitrile graft copolymers." The U.S. Dept. of Agriculture did the initial work on super absorbent compounds, of which Super Slurper is but one of several currently in the trade*. Private companies have followed up with more research and marketing efforts.

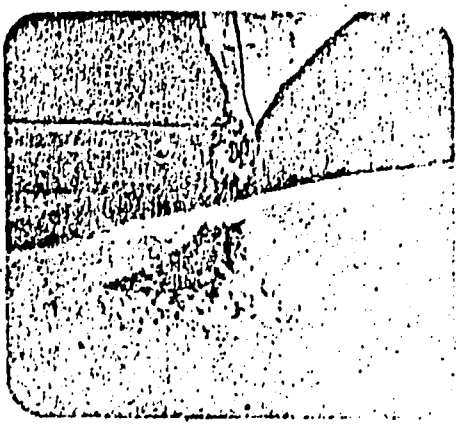
On contact with water, the Super Slurper particles swell and absorb water until saturated. The material does not dissolve. The swollen Super Slurper particles will release water to their surroundings, such as the soil or air, and then when wet again will absorb water back to their saturation point.

The amount of water super absorbents will hold depends largely on the manufacturing process, and on the quality of the water. They come as light-colored flaky substances, or talc-like powders. The powders hold more than flake types, but decompose faster. One gram of Super Slurper, a powder type, will hold about 80 grams of a 1 per cent saline (salt) solution, or about 1500 grams of distilled deionized water. The super absorbent compounds are biodegradable, and will last approximately six months in the soil, depending on conditions.

At first, the super absorbents were added to soils in very arid areas to increase their moisture-holding capacity. Since the early 1970's, many other uses have been found for this group of compounds, including medical bandages, pet litter, and horticultural applications. What we will be concerned with here are the horticultural uses.

Rates of application vary with the uses, soil types, water quality, and purity of the Super Slurper. Rates that are mentioned are general and should be considered as such. They are based

Continued on page 6



Super absorbent is a light flaky powder. It can absorb up to 1500 times its own weight of water.

In preparing potting mix, add the dry absorbent to the dry mix, then moisten it. The material is shown here beginning to pick up water.

*Another, named Terra-Sorb, is available in gardener sizes (4 and 8 oz.) from Trans Continental Energy Saving Products, 80 East Hartsdale Ave., Dept. FG, Hartsdale, N.Y. 10530.

Super Slurper is sold under that name by Wayside Gardens, Dept. FG, Hodges, S. C. 29695.

A product called Water Lock is listed by Mellinger's, 2310-FG W. South Range Rd., N. Lima, Ohio 44452.

Viterra 2, Aqua Stor, and Perma-sorb are other names reported for products of this type, and may be found in various retail local outlets.

Dr. Jim Alston is Director of Research for the Geo. W. Park Seed Co., Greenwood, S. C. He has been working with super absorbent compounds for several years.

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One way to apply it to established potted plants is as a thin slurry, merely poured on the soil.

Super Slurper

Continued from page 4

on the talc or powder type. You may vary them depending on conditions and results desired.

One popular way to use the compound is to mix it with a peat-lite (soilless) potting mixture to extend the intervals between waterings. If you generally water every day on pot soils that do not contain Super Slurper, you will need to water only every other day on soils with it added.

It is best to add the Super Slurper dry to the dry mix, at a rate of about 1 ounce per cubic yard, and combine them thoroughly before using. This special potting soil may then be used in all the ways you would normally use any potting mix, but you will not have to water it so frequently.

If you have established potted plants to which you would like to add Super Slurper, the way to do it is to mix a thin slurry and water the plants with it. Make the slurry thin enough to percolate quickly into the soil. Although not as good as mixing the material into the potting mix initially, this method will accomplish the purpose.

To increase the water holding capacity of garden soil, add Super Slurper at a rate of about eight ounces (dry) per 600 square feet of garden space. After application, mix and work the soil of the area to a depth of at least eight inches. It helps if you also add organic matter such as peat at this time. If your soil is sandy, use a higher rate of application of Super Slurper. If it is clayish, use less.

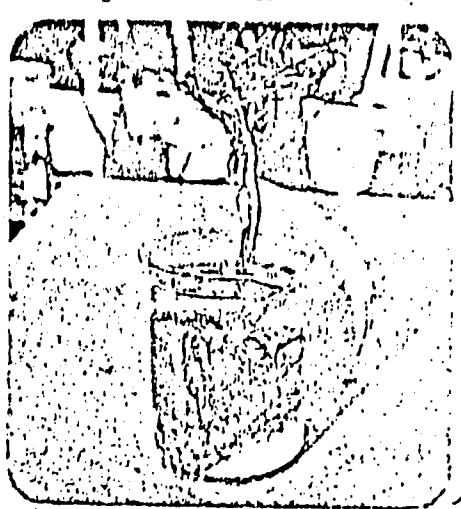
A favorite use of Super Slurper is on bare root plants at the time of transplanting. It helps their performance greatly. Make a slurry of Super Slurper about as thick as syrup. Use warm water (about 120 to 140 degrees), and add a little of the material at a time, stirring after each addition, until a uniform solution is obtained. First soak the roots of bare root plants in plain water; then dip them into the Super Slurper solution. Avoid shaking the roots, so as much absorbent as possible clings to them. After you finish planting the tree, shrub, or whatever, pour any remaining solution into the planting hole before completely filling it with soil.

Super Slurper is also used to aid germination as a seed coating. Only a very thin layer is needed to help maintain moisture around the seed while it sprouts. This is especially helpful in places where weather may turn dry after planting, and where irrigation is not available. It is a treatment practical mainly for those who are handling seeds in large quantity, as in farming or the seeding of roadsides. As there is a difficult technical process involved, of first coating seeds evenly with an adhesive so the absorbent will stick, I mention this use of Super Slurper only as a point of interest. Home gardeners will be much better off to put the material in the soil before planting, than to try to coat seeds with it.

A minor but interesting use for Super Slurper is in planting pre-germinated seed. In some places where weather at planting time is not warm enough to get good germination but where plants grow well once started, pre-germinated seeds are used to get uniform stands. The seeds are put in

Continued on page 34

Bare rooted plants in the process of transplanting may be dipped into a syrup-thick slurry of the absorbent, and planted with all that will cling. It holds a cushion of moisture around roots while the plant is becoming reestablished.



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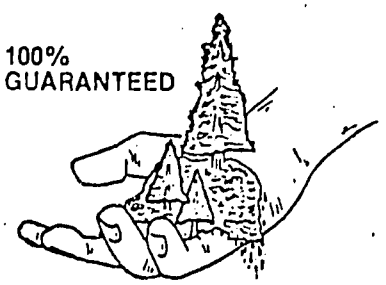

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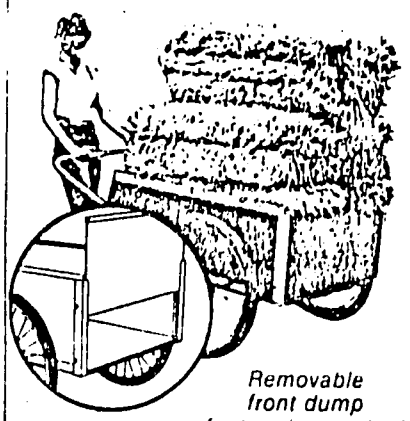

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NECTRIA CANKER

By M. W. Staples

There are a number of closely related cankers, but the most common form is *Nectria galligena* Bres., a major disease of birches and all too frequently on apple, sugar and red maples, aspen, black locust, walnut, oaks, lindens and other hardwoods.

The first sign of this canker is a dark, depressed, wet area, usually on the lower trunk or large branches. As the disease progresses the bark falls away, exposing the bare wood. In late summer and autumn the canker spreads to additional sapwood. In spring the tree attempts to heal over the injury with a roll of new callus tissue. By the end of summer the fungus has killed the new callus and a typical canker takes form.

Like most fungi, this disease is spread by airborne spores that may start a new infection wherever they can gain entry to the inner bark. All types of injury are suspected points of entry – wind and snow breakage, frost cracks, borers and mechanical injuries.

There is no way to provide 100 per cent protection. Trees in good vigor are resistant, trees under stress seem especially vulnerable. Sometimes cankers on branches can be eliminated by pruning. On trunk or large branches they can be chiseled out and disinfected, but diseased wood may extend beyond the visible signs.

Super Slurper

Continued from page 6

water which is kept aerated until tiny roots become visible. Then they are mixed into a slurry of Super Slurper and pumped through tubes of planting equipment into the seed furrows where they continue to grow. Although being used commercially, this method is a bit difficult for home owners – even though some may find a way to employ it.

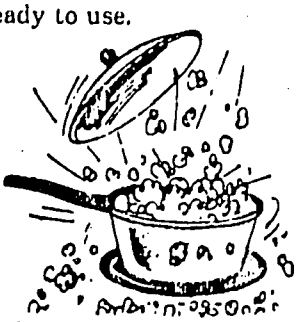
These are the main horticultural applications for Super Slurper up to the present. Other possible applications are probably just waiting for some imaginative person to think of them.

Good Popcorn

Continued from page 26

This is important. Plastic bags are not recommended, because most of them allow kernels to dry out. Properly stored in closed jars, popcorn will keep for several years. To bring corn back to proper moisture content, if it is too dry, fill a jar with corn leaving room for expansion, and add one to two tablespoons of water per quart of corn. Close jar and shake thoroughly to distribute moisture. After sitting overnight it is ready to use.

HOW TO POP GOOD CORN



The method of popping is the most important factor in good popcorn. The key is to supply high heat (450 to 480 degrees) all around the kernels. One of the main purposes in using oil in popping is to distribute heat. This is also the idea in stirring or shaking. Have the oil (any vegetable oil will do) just at the smoking point before adding the kernels. If the kernels are brought all at once to the very hot conditions, the popping (resulting from steam) should be completed quickly, in less than a minute, with nearly 100 per cent explosion of the kernels. On the other hand, if kernels are put into cool oil and allowed to heat up gradually, they will start to pop at about 250 degrees and there will be many partly popped or unpopped kernels. One half cup of kernels normally results in about four quarts of popped corn. Add salt after the corn is popped, not before. Otherwise, popcorn will be tough. It will be tough also if it is not emptied quickly out of the popper.

Nutritious, filling, good for the teeth and for digestion, and not highly caloric, popcorn is one of the best of all snack foods. In addition to eating it plain, you can create many other tasty treats with it – popcorn balls, candied corn, variously flavored popcorns, popcorn cake. These and other recipes are available free from the Brinkman Popall Popper Co. if you will send a self-addressed stamped envelope. Address: Brinkman Popall Popper Co., Inc., 4544 Wanamaker Rd., Dept. JB, Topeka, Kans. 66610.

Super Soil Moisturizer Challenges Others in Growing Industry

James F. Pritchard and James J. Quinn

MEETING THE DEMAND for increased watering efficiency requires employing the latest, water-related technology. Superabsorbents represent such a forward step; and advance that can be readily applied to increase survival, improve handling, conserve water, promote growth, and reduce maintenance

Superabsorbents, as soil amendments, are capable of absorbing hundreds, and even thousands of times their own weight in fluids. Each substance particle acts like an amazingly effective sponge, one which is insoluble and does not change the nature of the moisture that it absorbs.

TO gain an understanding of how these particles act to absorb moisture so efficiently, we can look at a simplified molecule of the material. Each particle or molecule can be considered as having two main "parallel" groups of atoms. These groups are periodically joined by connecting cross-links (as shown in diagram A). When water is added an electrical repulsion takes place causing the main branches of the molecules to repel each other, as the like poles of a magnet. When this happens, water is drawn in, between the branches resulting in a rapid swelling of each particle and a rapid absorption of water. At maximum capacity each particle will expand to over 30 times its original volume. When water evaporates or is extracted the material shrinks, returning to the unswollen state.

The absorption capacity of superabsorbents is affected by acidity and alkalinity (pH), conductivity and other variables that inhibit the material's expansion. Superabsorbents having a very high absorption capacity (over 800 times their weight in water) are typically sensitive to nutrients and other ionic substances, rapidly losing much of their water absorption capacity. It is not uncommon for a superabsorbent having an absorption capacity of 800 times its weight in pure water to absorb two or three hundred times its weight in actual use. Although pH of the absorbed fluid will also affect absorption, this should not present a problem in most plant related applications since the pH in the growing environment is normally within the ideal range (6 to 9) for optimum absorption.

Oxygen depletion or carbon dioxide buildup in the plant root zone is harmful or fatal to a plant. When superabsorbent particles are present in the growing media, they will, upon absorbing water, expand to many times their original size. As the particles expand, they open the soil media by forcing the particles apart, increasing aeration and

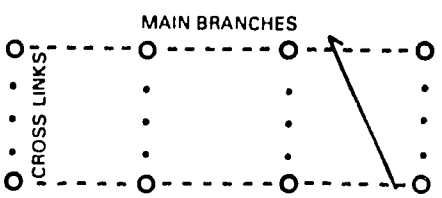


Diagram A. *Each molecule has in its structure two main parallel groups of atoms, periodically joined by connecting links.*

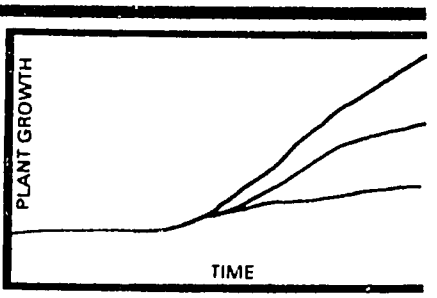


Diagram B *Top line: Treated with superabsorbents. Middle line: Growth with some stress. Bottom line: With continuous stress.*

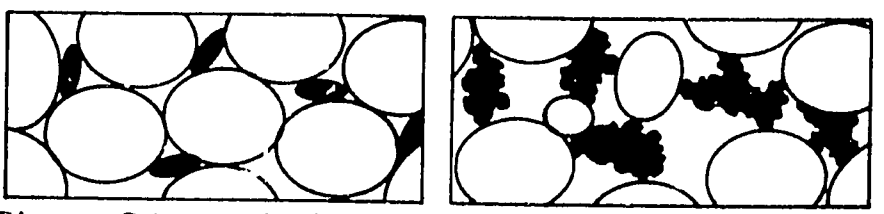


Diagram C *As superabsorbents (shown in black) swell, they force soil particles (shown in white) apart, opening passages for air and at the same time improving moisture availability.*

improving drainage. At the same time the high moisture along with high aeration provides faster growth and minimizes the danger of root rot. Once these particles have reached their maximum absorption, excess water will flow freely over and around the particles as it would flow over a saturated sponge. "Plugging" of the soil is not, therefore, a problem.

Several firms are producing superabsorbents. I am not able, however, to cite with confidence specific application rates, results and other details concerning all of these products. I will, therefore, discuss one product, Terra-sorb, with which we have been working since 1976. It has proven effective in the laboratory and, most importantly, in the professional growing environment.

Terra-sorb is used and accepted by the landscape and greenhouse industries. The product may be used in either a dry form or mixed with water to form a gel slurry.

LEADING nurseries are adding it to their growing media to improve moisture retention and promote aeration and drainage. Some of the benefits are a reduction in growing time (up to 25 percent), reduced irrigation frequency (up to 50 percent), increased shelf life and increased nutrient retention, due to reduced leaching of nutrients.

One Florida foliage plant grower wrote to us in July 1980, explaining his experiences with Terra-sorb. "I am writing to report on our experiences of the past 18 months with Terra-sorb," he reported. "We have examined the product closely in two applications related to our fern operation. In one application the material was utilized as a soil amendment in stock beds for the production of fern runners. In a second use, we tested the material in the production of 100-inch fern baskets. In the stock beds the product was incorporated into domestic peat at the rate of two pounds per cubic yard. We ran control beds adjacent to the two test beds and grew ferns under identical conditions of light and nutrient levels. After harvesting two crops in eight months we concluded that there was not a significant difference in the production of ferns in the two areas. This is not surprising since ground beds are very easy to keep keep moist.

"We ran similar tests with 10-inch fern baskets. The substance was used at the two pound rate and controls containing no Terra-sorb were grown under identical conditions. The differences were dramatic. The Terra-sorb treated baskets exhibited no transplant shock (transplant shock is very common with bare root ferns). Watering requirements were substantially reduced (I estimate approximately 50 percent). Of primary importance to us was the sharply reduced crop time. Normally we expect to finish a fern basket in about 20 weeks. We found that with Terra-sorb in the potting medium we reduced the time to finish the crop to 15 weeks, a savings of 25 percent. We attribute this difference to the water-holding capacity of this product.

"Further, we have considerable feedback from our customers concerning the performance of our plants on their shelves. They tell us consistently that our ferns are easier to maintain and require less watering in the stores.

"In summary, our assesment of Terra-sorb is very favorable. In some later tests we have determined that levels of the product as low as 1/2 pound per yard are effective, especially in smaller containers."

As this grower explained, there are conditions where applications of superabsorbents are not waranted. When ideal moisture conditions are maintained in the growing medium superabsorbents are of little value. However, the cost of maintaining the ideal moisture conditions should be examined and compared to the potential savings that could result if superabsorbents were applied.

In addition to incorporating Terra-sorb in the growing media, landscapers and nurserymen are improving survival and minimizing transplant shock by applying a gel slurry to the transplant roots. About one pound of material is combined with 20 to 30 gallons of water, to form a free-flowing gel that will adhere to the root structure. Because of the immediate availability of water, transplant shock is reduced and survival increases.

The superabsorbent is also affective for transplanting container grown nursery stock. About one tablespoon of material is evenly sprinkled into the hole and worked lightly into the soil prior to setting the transplant. When watered, the particles expand holding 50 percent or more water than the untreated media.

IN 1980 the University of Kentucky, conducted a study to evaluate the effectiveness of Terra-sorb and other transplant aids. Three replicates consisting of 10 sugar maple trees were evaluated. The test was conducted under the worst possible conditions. The plants were set very late (May 27); the nursery stock was in rather poor condition; the site was a slope with a fairly heavy cover; and the area received approximately 0.3 inches of rain from May 20 to July 1. Treating the transplants by dipping in a gel slurry consisting of one ounce of Terra-sorb/gallon of water resulted in a 298 percent increase in survival.

CHAMPION International Paper Company has been using Terra-sorb for the past year to gel coat seedlings prior to packing. This firm has modified its lifting machines by adding a water tank and pump. The seedlings are coated by pumping the Terra-sorb gel from the tank directly onto the bare roots as they approach the packing boxes. Prior to using the product a hydromulch was employed. This was inadequate and proved to be a production slowdown. In addition to providing moisture, the application of Terra-sorb improved production because of the increased efficiency of the application method and the subsequent reduction in handling time.

Clay continues to be used as a bare root moisture retention media and is often used in place of the mulch that had been used by Champion. Even though clay holds substantial quantities of water, most of the water is not in a plant-available form.

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Soil moisture is held in three basic forms. *Gravitational water* is water that freely moves through the soil due to the forces of gravity. This water is not usually used by the plant because it rapidly moves out of the soil. *Capillary water* is water that is held by cohesion (attraction) between water molecules. Most of this water is available to plants.

Capillary water can be considered as being in the form of a thick film around the soil particles. The water moves to the point of highest tension (lowest pressure). The root hairs create a low pressure and are capable of drawing moisture until the attraction between the soil and the water molecules is greater than the attractive forces of the roots (permanent wilting point). *Hygroscopic water* is water held by adhesion in the form of very thin films around the soil particles. It is not usually available to plants. As soils become finer textured there is increased adhesion between the water and the soil particles. This adhesion binds the water so tightly that it is not plant available. This is the situation with clay.

When superabsorbents are mixed into the growing medium, the material absorbs gravitational (not usually available to plants) and capillary water. This water is held by a mechanism similar to cohesion, providing water that can be readily extracted by the plant root promoting ideal growing conditions.

RECENT STUDIES at Auburn University indicate that Terra-sorb can be effectively added to pine bark media to reduce water stress and increase nutrient retention. With the increasing price of peat moss the use of bark will increase dramatically. Four rates of the soil amendment and a control were used on an all pine bark medium. Four-inch plastic containers were filled with unamended pine bark, or pine bark medium plus one, two, three, or four pounds of Terra-sorb per cubic yard. Pots were fertilized from one to five times using a 200 ppm NPK soluble fertilizer from a 20-20-20 source.

The weight of four-inch containers at field capacity increased the first day of watering by 41, 85, 117 and 131 percent (figures correspond to amount of Terra-sorb added to the media). A subsequent test showed an increase of 19, 50, 66 and 70 percent. The difference in percentage is attributed to the bark not being at moisture equilibrium during the first test. However, a very significant increase in moisture retention is still noted.

The use of this material to enhance the water holding capacity also increased the nutrient holding capacity of the pine bark medium. Soil nitrogen increased three, six and nine percent as the weight of Terra-sorb increased from one to three pounds per cubic yard. Generally the nitrogen content increased by one percent with subsequent waterings. Nitrogen concentration increased with increasing amounts of Terra-sorb, up to three pounds per cubic yard.

THE UNIVERSITY OF Georgia evaluated the soil amendment for its effectiveness in increasing water holding capacity and for reducing required watering of a soilless growing medium (Metro-Mix 300). In addition, germination percents and rates of *Phaseolus volgaris*, "Topcrop" bushbean were compared. Water holding capacity increased and required watering decreased with increasing rates of Terra-sorb in four-inch containers. There were similar changes in six-inch containers.

Phaseolus volgaris was chosen as the test plant because it has a large transpiration surface area, and would, therefore, be expected to respond rapidly to changes in soil water content. The weight at the wilting point was reduced by eight and 16 percent for the four-inch pots and four and nine percent for the six-inch pots at the 2.2 and 3.3 pound per cubic yard rates.

Germination in the four-inch containers increased from 48 percent (control) to 83 percent (1.2 and 2.2 pound per cubic yard rate) to 90 percent at the 3.3 pound per cubic yard rate. Germination in the six-inch pots was not significantly affected by the Terra-sorb since the germination rate, in the control group, was very high.

Superabsorbents are ideal for use as a seed bed amendment, gel dip and other uses described previously. Superabsorbents are being evaluated as seed coatings to improve germination and promote growth, as a water thickening agent to aid in fighting forest fires, and as a mulch additive to improve moisture retention in seed beds.

Other applications will be recognized as the value of this technology spreads throughout the the industry.

THE COST for using superabsorbents is reasonable, especially when viewed in relation to the benifits. Typical cost for applying Terra-sorb are about: $8.50 to treat a yard of media, which equates to about six cents to treat a gallon container; five cents to treat a 72-cell bedding flat, and one cent to gel dip 50 seedlings; 8/10 of a cent per square foor sodding or hydromulching and 40 cents for a one foot rootball.

For the landscape architect and landscaper, this material offers control of moisture beyond the nursery with a substantial savings in water, labor and energy. The substance is used by leading landscapers and specified by landscape architects for: transplanting, sodding, seeding new lawns and turf, hydro-mulching and hydro-seeding, and interiorscaping.

For transplanting, the amendment is sprinkled evenly into the pit and, if practical, worked lightly into the soil, prior to setting the ball, and smaller transplants can be treated by dipping the roots in a Terra-sorb gel slurry. For sodding, the material is broadcast over the area to be sodded prior to to laying.

A leading landscaper in Atlanta, Georgia, reports:

"In our landscaping project at an Atlanta condominium project, we used a layer of Terra-sorb between the ground and the sod that we laid. Our problems included many narrow spaces, extreme heat and sporadic watering. Our goal was to minimize shock to the sod and quickly establish a green cover. We definitly feel that Terra-sorb helped us achieve these goals."

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In hydro-mulching, Terra-sorb is mixed with the mulch, fertilizer, water and seed. The amendment provides the seed with moisture, promoting germination. In addition, at higher rates of application (above 75 pounds per acre), the material acts as a tacker and binder minimizing wind and rain erosion.

Terra-sorb is also useful in interiorscaping. The material is mixed evenly into the growing media to provide ideal soil moisture conditions. The use of this particular amendment can result in a dramatic change in watering frequency. Consider the labor savings that results from doubling or even tripling the time between required waterings.

Note that soil that contains this substance may feel dry yet contain substantial quantities of plant available water. Watering should be accomplished when the plant shows evidence of requiring water. When watering is required, water slowly, and thoroughly to permit optimum superabsorbent absorption.

Employing Terra-sorb is especially desirable for those hard to reach planters in hotel interiors and similar locations. Please note that we do not recommend using superabsorbents with cut flowers. Our experience has shown that accelerated wilting can result from the superabsorbent drawing moisture from the cutting. Plant roots act as check valves, and until established, moisture can be easily drawn from the cutting by the superabsorbent.

Reports we receive concerning the use of this material are well summarized in the words of Sara Groves, Horticulturist for the Georgia Institute of Technology:

"Having Terra-sorb is like having a built in baby sitter for our horticultural projects. We have found that newly planted seed flats, seed beds, transplanted flowers and shrubs and all growing plants are well protected with it. In addition, the substance reduces labor and saves production costs."

Edited from a speech to the American Institute of Landscape Architects, Las Vegas, Nevada, August 22, 1981, by James J. Quinn, President, Industrial Services International, Inc., Bradenton, Florida.

Editor's Note:

This feature is primarily an evaluation of the soil amending properties of Terra-sorb, a product of Industrial Services International, Inc., Bradenton, Florida. The subject represents an interesting follow-up to "Evaluation of VITERRA 2 Hydrogel As a Medium Amendment" which appeared in the October 1981 issue of ORNAMENTALS SOUTH.

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Phillis Windle

The 1981 Rolex Awards For Outstanding Enterprise

The Rolex Awards for Enterprise is an international program to provide financial help and special encouragement for individuals whose projects have broken new ground in their chosen fields. These projects capture that spirit of enterprise which has been such a characteristic of the development of the Rolex watch. Here are the five award winners of 1981 with a resume of their projects.

A Blueprint for Disarmament — Seymour Melman

If global disarmament ever is to be achieved, one vital step in the process will be to convert industrial economics from military to civilian work. Seymour Melman, an American Professor of Industrial Engineering, has been exploring myriad technical, economic and organizational changes required to make such conversions work.

As industrial economics vary widely, Professor Melman is formulating three representative models for conversion: the U.S.A. and Western Europe, the Socialist countries, and the less-developed countries.

His 1981 Rolex Award for Enterprise will enable Professor Melman to develop his blueprints for conversion.

To Save the Snow Leopard — Rodney Jackson

In the snow-covered Nepalese Himalayas lives the elusive, endangered snow leopard.

Mr. Rodney Jackson, a wildlife biologist, plans to capture live several specimens of these magnificent creatures and collar them with radio transmitters. Very little is known about the snow leopard, but we do know that it faces almost certain extinction as man encroaches upon its habitat.

Mr. Jackson's 1981 Rolex Award for Enterprise will expand our knowledge of the snow leopard and its environment and help save a beautiful species from extinction.

Preserving Mexican Folk Music — Eduardo Llerenas

The culture of Mexican folk music is one of the richest in the world.

However, due to the influence of TV, radio and the record player, it is a culture fast disappearing.

With two companions, Mr. Eduardo Llerenas has made over eighty trips into the remotest parts of Mexico in order to record, compare and preserve the country's traditional songs.

When completed, the work of Mr. Llerenas will provide an accurate and lively record of the folk music of Mexico.

His 1981 Rolex Award for Enterprise will help Mr. Llerenas to complete this valuable undertaking.

Re-fertilizing the Earth — Andre Martin

All over the world, vast tracts of fire-damaged land lie waste. To return land such as this to its original fertility is the aim Andre Martin has set himself. The undergrowth, brushwood and scrub, the only things which will grow on such land, are cleared and converted into an organically rich compost.

In a successful experiment in France, twenty previously desolate acres have been returned to successful cultivation using this method.

His 1981 Rolex Award for Enterprise is reward for Andre Martin's truly fertile imagination.

Let the Sperm Whale Live — Milan Mirkovic

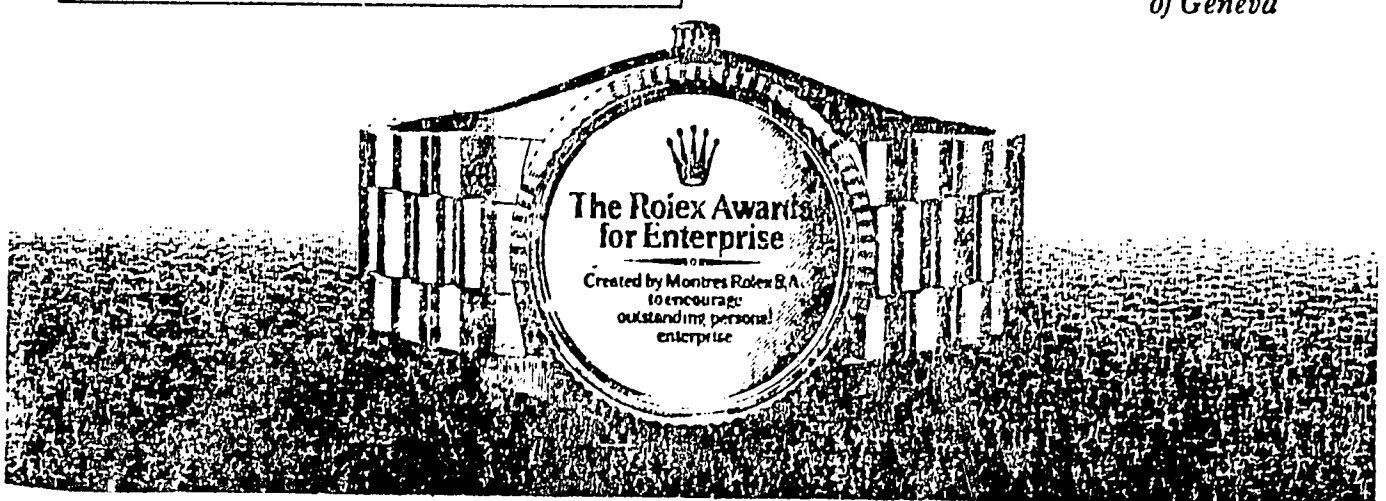
Mr. Milan Mirkovic has devised a novel irrigation method for the growing of the jojoba bush. The jojoba nut contains an oil which is almost identical in properties to sperm whale oil and therefore could become a commercial alternative to sperm whale slaughter.

However, it is only Mr. Mirkovic's use of containers filled with earth and a water absorbent polymer (it holds 1,000 times its own weight of water, thus dramatically reducing the cost of irrigation) which may make the cultivation of the jojoba a commercial possibility. Mr. Mirkovic's 1981 Rolex Award for Enterprise should help in saving the sperm whale.

Each of these five winners has received 50,000 Swiss francs as a contribution to the fulfillment of his work. Each has also received a specially inscribed Rolex Oyster as a tribute.

The 1981 Rolex Awards for Enterprise: Help and encouragement to those who have demonstrated truly outstanding enterprise.

ROLEX
of Geneva



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FEDERAL REPORT

D Finds Nothing Exceeds Like Success

By Cass Peterson
Washington Post Staff Writer

ie a problem to envy, but / for International Devel- having a little trouble iccess.

oot of AID's dilemma is iental program it helped September in Zimbabwe. d a technology exhibition, AID play matchmaker be- entrepreneurs and poten- s in the Third World.

a is that U.S. firms get s, which create jobs here, developing countries get that can boost ag, culture tion and create jobs th goals are solidly in line lministration's aims.

r months after its exper / raves in Zimbabwe, the on ice at AID. The prob- ology exhibitions are a lot fairs. And trade fairs are AID's job description.

ie agency can justify an under legislative help [illegible] coun- [illegible] signals ap- ren't sure they want to the turf of the Commerce t and help [illegible] business profit, even if Commerce say. It is, according to a al aide, a case of "the bu- war with itself."

D did is relatively simple: 600 in agency funds, a le contribution and a pri- actor, the agency put to S. pavilion for the event, evelopment Technology last September in Bu- ibabwe.

e pavilion, about 40 U.S. yed a smorgasbord of the counterculture gadgetry he field as "appropriate There were windmills, ed stoves and refrigera- and beehives.

ucts were not the sort of General Dynamics and ventures and overseas manufacturing and marketing agreements that could create jobs in the United States and Africa.

In all, according to a preliminary evaluation by AID's project officer, "business arrangements made within the U.S. pavilion ranged from $4 [million] to $6 million. There is potential for the final figure to substantially exceed this amount."

In a cable to the State Department after the Zimbabwe event, AID's office in Ouagadougou said Upper Volta's representatives were "delighted . . . . Instead of the giant corporations they had expected, they met with 'small- and medium-sized' firms promoting technologies appropriate to the African environment." The Near East mission of AID chimed in enthusiastically, suggesting a similar effort for an upcoming technology fair in Manila.

But in a recent House Small Business subcommittee hearing, Barbara Otis said the agency's Bureau of Private Enterprise is not focusing on development technology.

Rep. Berkley W. Bedell (D-Iowa), chairman of the Small Business subcommittee that explored the issue in December, was exasperated at what he called a "bureaucratic nightmare" of missions and mandates and agency priorities. "I have to tell you I think our policies are just absolutely crazy," Bedell said.

'Terra' Firm Sees Bonanza

James J. Quinn thinks he has a better mousetrap, but he doesn't expect the world to beat a path to his door. He would, however, like a little help beating a path to the world's door.

Quinn, president of Industrial Services International Inc. of Bradenton, Fla., was among the American businessmen who went to Zimbabwe last September at the expense of the Agency for International Development.

AID was experimenting with ways to transfer technology to Third World countries. Quinn was looking to expand the market for his product: Terra-sorb, a super-absorbent soil additive that captures and holds moisture where growing plants can use it.

AID is still evaluating its experiment, but Quinn is ready to issue his opinion: "It was an absolute success. No question about it."

As a result of contacts made during the exhibition, Quinn's firm is working on marketing agreements with three firms in Zimbabwe and two in South Africa. Crates of Terra-sorb left by ship last month for Africa.

There really isn't much new about Terra-sorb, a starch polymer that looks like coarse sawdust. The Agriculture Department developed the technology more than 10 years ago. Government scientists, intrigued by its ability to soak up hundreds of times its own weight in water, called it "super slurper." But the technology sat on the shelf until Quinn's firm saw its practical potential.

What the product does is hold moisture in the soil, where plants can use it, rather than letting rain run off or sink to the water table. The Bradenton firm sells tons of it now, to plant nurseries and other horticultural operations, as well as to cemeteries.

The firm is experimenting with Terra-sorb seed coatings as a way to improve germination rates and give tender seedlings a head start.

Quinn's company says the product has great potential for helping developing countries increase their food production, and he says he's eager to start a manufacturing plant in southern Africa with African employes.

"It's a whole lot better than just pumping money into those countries," Quinn said. "And most of them aren't interested in having another Borden or Dow sitting in the back yard."

—Cass Peterson

ELSEWHERE

- *CPSC majority sends warning on agency's budget—Page C11*
- *Leahy asks the White House to review the role of agriculture assistant secretary in stock fraud case—Page A3*
- *Civil rights lawyers ask court to overturn Reagan administration's [illegible]*

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SECTION III

"TERRA-SORB"

Industrial Services International, Inc.

a. See For Yourself.

b. Terra-Sorb: A Water Management "Tool" for World Crop Production.

c. Terra-Sorb "Super Soil Moisturizer": International Applications.

d. Terra-Sorb - What Is It?

e. Potential Applications for Terra-Sorb.

f. A Testimonial Report.

g. Terra-Sorb in Greenhouse Use.

h. Terra-Sorb in Transplanting.

i. Terra-Sorb in Landscaping.

j. Seed Coatings.

k. Questions Most Asked About Terra-Sorb.

l. Terra-Sorb in the Forestry Market.

m. Terra-Sorb in Combination With Hydromulching.

n. Terra-Sorb 200G Super Seed Moisturizer for Seed Coatirg.

o. International Bulk Price Schedule.

p. Terra-Sorb Specifications Guide for Landscape Architects.

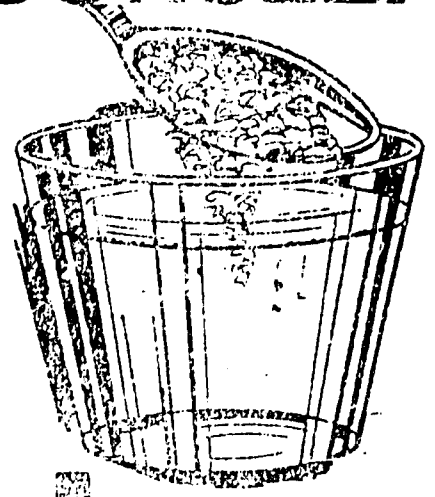
q. Forestry and Ornamental Users.

r. What Others Say About Terra-Sorb.

s. Here Are Just A Few of Our Terra-Sorb Forestry Customers.

SEE FOR YOURSELF!

Sprinkle one teaspoon into a 2 oz. glass of water. Next, watch as each insoluble flake absorbs hundreds of times its weight storing available moisture for plants and reducing water use dramatically.



...why terra-sorb*T.M. is the *Super Soil Moisturizer!*

ONE POUND OF TERRA-SORB ABSORBS 20-25 GALLONS OF PLANT AVAILABLE WATER.

HOW IT WORKS

When mixed into the growing media each tiny particle of Terra-Sorb® acts like an amazingly efficient sponge which will expand to over thirty times its original volume. Terra-Sorb® will not change the nature of the moisture it absorbs. When water evaporates or is extracted from Terra-Sorb®, the material returns to an unswollen state, increasing the air pore space in the soil, thereby increasing aeration. When water is again introduced, Terra-Sorb® will re-swell.

MANY USES

LANDSCAPING

- Sodding
- Transplanting
- Hydromulching
- Hydroseeding

NURSERY AND GREENHOUSE

- Propagating
- Hanging baskets
- Bedding plants
- Bare root shipping media

FARMING

- Transplant dip
- Seedcoating
- Plug mix
- Fluid drilling

Plants grown with Terra-Sorb amended media can reach saleable size up to 30% faster!

Terra-Sorb increases the water-holding capacity of any soil mixture without causing over-watering problems. Excess water flows freely over water swollen Terra-Sorb particles as it would flow over a saturated sponge.

Terra-Sorb was developed to condition any planting media for better water control. It releases the right amount of water at the right time.

Terra-Sorb reduces watering needs.

Terra-Sorb helps prevent transplant shock.

Terra-Sorb provides for healthier root systems, resulting in healthier plants.

Terra-Sorb speeds plant growth.

Terra-Sorb promotes more uniform plant growth in hard to maintain patio pots, window boxes, hanging baskets, etc.

Terra-Sorb acts as a "baby sitter" for plants extending the period between waterings. Keeps plants fresh while you vacation.

Terra-Sorb improves aeration and drainage of growing media.

Terra-Sorb reduces media requirements by 10% to 15% in small containers.

Terra-Sorb is easy to use.

Terra-Sorb® is a product of Industrial Services International, Inc.
For further information or to place an order contact:

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*Terra-Sorb® is a gelatinized, starch-hydrolized polyacrylonitrile graft copolymer using potassium hydroxide.

TERRA-SORB
A WATER MANAGEMENT "TOOL"
FOR WORLD CROP PRODUCTION

By

James F. Pritchard and James J. Quinn

Industrial Services International, Inc.
P.O. Box 10834
Bradenton, Florida 33507 U.S.A.
Phone 813/792-7778 Telex 89-8388 (AEMPOWER/WHEN)

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Auburn University, Dr. Frederick Perry. TERRA-SORB CAN BE EFFECTIVELY ADDED TO PINE BARK MEDIA TO REDUCE WATER STRESS AND INCREASE NUTRIENT RETENTION.

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INTRODUCTION

TERRA-SORB is a material that will increase crop yield, reduce losses, conserve water, reduce labor costs and in other ways benefit people in the "green industry". Farmers, foresters, greenhouse operators, conservationists and others concerned with the growing of plants will recognize the benefit of TERRA-SORB and the new technology that it represents.

There are many applications for TERRA-SORB in other industries, however, this paper will address only those applications relating to the growing of plants.

Copyright 1983 by Industrial Services International, Inc.

GENERAL BENEFITS

Agricultural and forestry production throughout the world can be increased through the use of TERRA-SORB, a product of Industrial Services International, Inc., Bradenton, Florida. TERRA-SORB increases survival, improves germination, reduces transplant shock, increases yield, promotes faster growth minimizes erosion and permits more efficient use of water resources. TERRA-SORB's greatest potential benefit lies in those areas where there is significant moisture stress. This paper will introduce TERRA-SORB, describe superabsorbent technology and highlight the results of laboratory tests and field applications.

Superabsorbents have proven to be of major benefit to:

- o Foresters.
- o Farmers.
- o Greenhouse growers.
- o Soil conservationists.

INTERNATIONAL APPLICATIONS

TERRA-SORB's potential applications in developing countries are practically limitless. Dry land and rain fed agriculture projects such as those sponsored by the U.S. Agency for International Development seem particularly suited for the use of this technology since, by definition, these projects are predicated on the absence of consistent predictable amounts of precipitation. In such an environment, TERRA-SORB use may make the difference between agricultural self-sufficiency and the continuation of a pattern of importing basic foodstuffs. Experiments conducted in a semi-arid area of United States showed twelve to fifteen per cent increase in wheat yields in those fields using TERRA-SORB compared to those where it was not used. There is no reason to believe that different results would be obtained in developing countries.

Reforestation projects are also suitable for TERRA-SORB use. Over one half billion forestry seedlings were treated with TERRA-SORB in FY '82.

TERRA-SORB, WHAT IT IS AND HOW IT WORKS

TERRA-SORB is a material that acts like a supersponge, absorbing and storing hundreds of times its weight in plant available water, releasing it to the plant on demand. TERRA-SORB is a water management tool. In addition to its amazing moisture retention, TERRA-SORB acts to promote aeration and in many other ways benefits the grower.

HOW IT WORKS:

To gain an understanding of how these particles act to absorb moisture so efficiently, we can consider a simplified molecule of the material. Each particle or molecule can be considered as having two main "parallel" groups of atoms. These groups are periodically joined by connecting cross-links like the rungs of a ladder (as shown in diagram A).

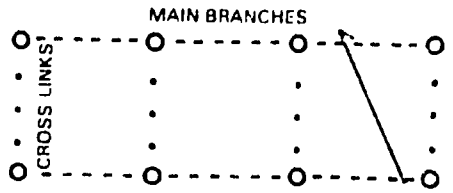

Diagram A. *Each molecule has in its structure two main parallel groups of atoms, periodically joined by connecting links.*

When water comes into contact with a superabsorbent, an electrical repulsion takes place, causing the main branches of the molecule to repel each other as the like poles of a magnet. When this happens, water is drawn between the branches resulting in a rapid swelling of each particle. At maximum capacity, each particle will expand to over thirty times its original volume. When water evaporates or is extracted, the material shrinks, returning to the unswollen state. When water is again added, the material will re-swell absorbing the water as described previously.

FACTORS AFFECTING ABSORBENCY:
The absorption capacity of superabsorbents is affected by acidity and alkalinity (pH), conductivity, and other variables that inhibit expansion of the gel particles. The pH of the absorbed fluid should not present a problem in most plant related applications since the pH in the growing environment is normally within the ideal range for optimum absorption. Fertilizers, salts and other chemicals present in the growing environment can, however, cause a significant reduction in stated absorbency.

Superabsorbents having a very high absorption capacity (eg. over 1000 times their dry weight in water) are typically sensitive to such "impurities", losing a large percentage of their claimed capacity. It is not uncommon for a superabsorbent having an absorption capacity of 1000 times its weight in pure water to absorb 200 or 300 times its weight in actual use because of the effect of such materials as fertilizers and other chemicals.

Selecting the proper application rate, especially for very high capacity superabsorbents can present a serious concern. The user must decide whether the material should be applied at the recommended rate, a rate which may not be based on "real world" conditions, or at a higher rate which considers the characteristics of the particular growing environment.

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Applying a superabsorbent at a rate which produces too much gel at the plant roots can cause serious problems, including plant death, by inhibiting root aeration. Using superabsorbents at too low an application rate will result in failure to obtain the desired benefit.

Using superabsorbents having a lower sensitivity to such variables, as discussed previously, takes the guesswork out of selecting the proper application rate, greatly simplifying the successful, effective application of superabsorbent technology. Another method of eliminating the guesswork is through the use of TERRA-SORB 200G to coat seeds prior to planting. This is especially appropriate in a developing country context where farmers may lack the know-how to properly mix and add TERRA-SORB flakes (see p. 5 for more information on TERRA-SORB 200G).

EFFECTIVE LIFE:
TERRA-SORB remains effective through many swell-shrink cycles. In the growing environment the superabsorbent remains effective from a period of about six months to several years. After biodegrading, what remains functions as soil amendment to improve aeration and other soil characteristics. In fact, biodegradation converts TERRA-SORB to virtually the same material as a soil amendment marketed by Monsanto in the 50's called KRILIUM.

Dr. Jim Alston, Director of Research for the George W. Park Seed Co., reported in the June-July, 1982 issue of FLOWER AND GARDEN MAGAZINE, that superabsorbents in the powder form hold more water than flake type materials such as TERRA-SORB. However, the powder forms decompose faster.

PROMOTES FASTER GROWTH:
Most plants are watered on a schedule or when signs of wilting appear. Such methods do not ensure that the plant has adequate water for optimum growth. In fact, by the time a plant shows signs that it needs water, it has long since stopped growing. Using TERRA-SORB allows the plant to obtain water as needed for optimum, uniform growth (as illustrated in diagram B). There is no slow down due to too much or too little water.

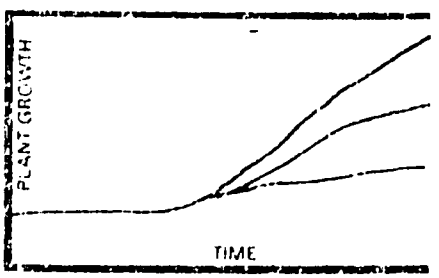

Diagram B Top line: Treated with superabsorbents. Middle line: Growth with some stress Bottom line: With continuous stress.

At the same time, in an environment where there is moisture stress, faster growth is promoted by the gradual, phased release of stored water. This serves to ameliorate the "rain-runoff-drought" cycle in arid and semi-arid areas.

IMPROVES AERATION AND DRAINAGE, DOES NOT PROMOTE ROOT ROT:
Oxygen depletion or carbon dioxide buildup in the plant root zone is harmful or fatal to a plant. When superabsorbent particles are present in the growing media, they will, upon absorbing water, expand to many times their original volume (as illustrated in diagram C). This expansion opens, and exercises the growing media by forcing soil particles apart, increasing aeration and improving drainage. Once these particles reach their maximum absorption, excess water flows freely over and around the particles as it would flow over a saturated sponge. TERRA-SORB does not, therefore, cause "plugging" of the soil. The combination of ideal water availability combined with good aeration promotes faster growth and minimizes the danger of root rot.

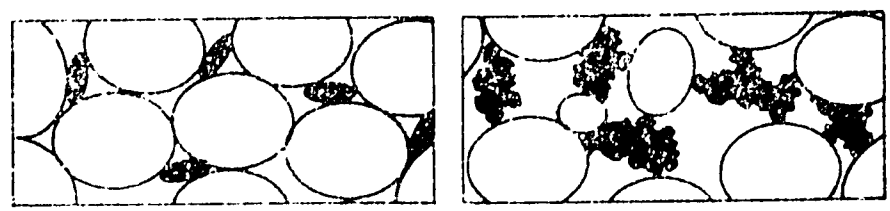

Diagram C As superabsorbents (shown in black) swell, they force soil particles (shown in white) apart, opening passages for air and at the same time improving moisture availability.

MAKES MORE EFFICIENT USE OF WATER:
A major advantage of superabsorbents is their ability to make use of gravitational water, water which is usually not available to plants, as well as capillary water. As explained below, soil moisture is held in three basic forms:

1. Gravitational water is water that freely moves through the soil due to the force of gravity. This water cannot usually be used by the plant because it rapidly moves out of the soil.

2. Capillary water is water that is held very loosely around the soil particles. The water is held by cohesion (attraction between like molecules). Most of this water is available to plants. Capillary water can be considered as being in the form of a thick film around the soil

particles. The water moves to the point of highest tension (lowest pressure). The root hairs create a low pressure and are capable of drawing moisture until the attraction between the soil and the water molecules exceeds the attractive forces of the roots (permanent wilting point).

3. Hygroscopic water is water held in the form of a very thin film around soil particles. It is not usually available to plants.

WIDELY ACCEPTED:
TERRA-SORB is overwhelmingly accepted by the growing industry in the United States. Magazine articles, testimonials, research reports and other materials, along with our satisfied customers, attest to the proven effectiveness of TERRA-SORB. The attached appendix includes summaries of reports on TERRA-SORB by leading researchers.

USES OF TERRA-SORB

There are five basic ways to use TERRA-SORB:

1. As a seed coating (TERRA-SORB 200G).
2. Adding to growing media in the dry form.
3. As a gel carrier for pregerminated seeds.
4. As a gel dip when combined with water.
5. Broadcasting over surfaces prior to planting or seeding.

TERRA-SORB 200G FOR SEED COATING

A specially modified form of TERRA-SORB has been developed specifically for seed coating applications. Moisture absorbing particles in TERRA-SORB 200G expand as they draw moisture from the humid air in the soil or from liquid water. In expanding they form a gel "fuzz" at the seed surface. Moisture held by the gel softens seed tissues promoting rapid germination. Plants grow faster because moisture is readily available to the seedling. TERRA-SORB 200G can be mixed with the seed at a central distribution facility, thus eliminating the need for the individual farmer to concern himself with adding the material.

TERRA-SORB 200G is a powder that is applied by simply mixing it with dry seed in the ratio of one pound per hundred pounds of dry seed. It is ideal for sweep, hopper box application. Because TERRA-SORB 200G is not abrasive, and since it contains graphite, it lubricates planting equipment, thereby maximizing planting efficiency. For seeds with a smooth, waxy surface, a small amount of water may be added to the seed to aid in coating.

RESULTS OF USING TERRA-SORB 200G IN AGRICULTURE:
Tests conducted with wheat, oats, beans and other crops have shown that the use of TERRA-SORB as a seed coating can result in a 10-15 percent increase in crop value per acre. Average yield increases of 5-7 bushels per acre have been reported.

Soy bean yield has been increased by 26 percent. Jim Powers, a grower and agricultural consultant in Zachary, Louisiana tested TERRA-SORB 200G with soy beans in 1981. Fourteen rows were treated. Treated plants averaged 28 inches in height, the untreated plants averaged 16 inches. Beans on the treated plants were larger and uniform in size. In addition, the majority of beans in the top pods of the treated plants had three or more beans as opposed to two on the untreated group.

Extrapolated harvest data, based on the fourteen treated rows indicates that the yield per acre would be increased by 26 percent; 38 bushels for the treated plants as opposed to 30 bushels for the untreated ones.

RESULTS WITH GRASSES:
In 1982 the U.S. Soil Conservation Service conducted a series of tests at the U.S. Army Corps of Engineers floodwater retarding structure (Gallesteo Dam) in Albuquerque, New Mexico using grasses which were treated with TERRA-SORB 200G, as well as untreated grasses. As reported by the Soil Conservation Service, using TERRA-SORB 200G doubled the plant growth (height) and accelerated seed production.

On the treated area 'Ganada' Yellow Bluestem, 'Hacita' Blue Grama, and an experimental strain of Sideoats Grama all made seed. On the untreated area, only a single plant of Sideoats Grama which had a seed stalk was found.

The treated side had plants which were about four inches tall. The best plants on the untreated side were about two inches tall.

ADDING TERRA-SORB TO THE GROWING MEDIA IN THE DRY FORM:
For transplanting trees, shrubs and large plants, the superabsorbent is sprinkled evenly into the hole prior to setting the plant or mixed into the backfill. Once the superabsorbent has been added the hole is filled and watered in as usual. Superabsorbents should not be simply poured into the hole as they would, upon watering, form a thick gel ball around the root which could prevent aeration.

In agriculture superabsorbents can be banded into the planting furrow. In applications with tobacco, this method resulted in an average increase in leaf length of 9 inches (36 inches compared with 27 inches for the control plants). The height of the treated plants was 69 inches, the untreated plants averaged 51 inches. The rate of application was three pounds of TERRA-SORB per acre.

USE AS A GEL CARRIER FOR PREGERMINATED SEEDS (GEL SEEDING/FLUID DRILLING):

Superabsorbents are very effective when mixed with water and pregerminated seeds for gel seeding applications. Special machines plant the pregerminated seeds which are suspended in the gel mixture. The gel protects the seed and provides a source of moisture for the emerging plant.

A modification of this process is to mix a superabsorbent with a plug mix or soil, pregerminated seed and water. Although only recently developed, this method of application seems superior to traditional gel seeding applications.

USING TERRA-SORB AS A GEL DIP
Small plants are transplanted and shipped using a gel slurry around the roots. The gel is made by combining a small amount of the superabsorbent with water; for example, one pound for twenty five gallons of water. Dipping the roots keeps them moist, increasing survival and minimizing transplant shock. Severral divisions of The U.S. Army Corps of Engineers and the U.S. Forest Service specify the use of TERRA-SORB. As stated previously, over one half billion forestry seedlings were treated with TERRA-SORB in FY '82. Most of these trees were gel treated.

BROADCASTING OVER SURFACES PRIOR TO SEEDING OR PLANTING:
Superabsorbents are broadcast over an area prior to seeding or planting to enhance moisture retention, promote emergence and increase germination.

NEED FOR ADDITIONAL STUDIES:

Because of the wide range of potential applications, both domestic and international, there are many areas for additional research. Some suggested studies include:

Evaluating the effect of employing superabsorbent technology on crop production in developing countries.

Determining the effectiveness of using TERRA-SORB, applied in a variety of application methods on major crops including rice, wheat, and tobacco.

Evaluating the effect of superabsorbents as additives to various spray applied water-base materials such as: pesticides, growth regulators, and herbicides. The incorporation of superabsorbents will reduce drift, minimize runoff, and may increase effectiveness. A reduced application rate would minimize any harmful environmental impact and reduce cost.

Evaluating the effectiveness of superabsorbents as a top dressing amendment for seed flats to promote faster germination, reduce

misting and leaching, reducing foliage disease and maintenance.

Evaluating the acceptance of this technology by farmers in less developed countries.

Evaluating the general suitability of superabsorbent technology to nursery operations in developing countries.

Evaluating the effect of TERRA-SORB in minimizing erosion. The rapid establishment of a healthy ground cover will do much to minimize soil erosion. Superabsorbents are likely to promote such growth.

Evaluating the water conservation potential of employing superabsorbent technology in developing countries.

CONCLUSION

Adding any additional material beyond those substances currently used such as fertilizers, pesticides and herbicides adds to the cost of the operation. The cost, however must be viewed in its relation to the benefit.

The cost of using TERRA-SORB is very reasonable, especially considering advantages that it can provide such as:

- o Increased efficiency of water use.
- o Increased survival.
- o Increased rate of growth.
- o Increased shelf life.
- o Increased germination.
- o Reduced transplant shock.
- o Reduced crop growing time.

One hundred pounds of seed can be treated with TERRA-SORB 200G for approximately 6 dollars. Because of the varying quantities of seed planted per acre for various crops, the cost per acre of seed treatment can vary from as little as 10 cents for crops such as tomatoes (1/2 pound of seed per acre) to about 7 dollars per acre for wheat (120 pounds of seed per acre).

Typical costs for applying TERRA-SORB are: less than 10 dollars to treat a cubic yard of media, which equates to about 6 cents to treat a gallon container, 4 cents to treat an eight-inch hanging basket and 6 cents to treat a 72-cell bedding flat. Used as a gel dip, 50 seedlings can be

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treated for 1 cent. Cost for use in sodding or hydromulching is 8/10 of a cent per square foot. In transplanting, a plant with a one foot diameter root ball can be treated for 40 cents. The cost for treating 10,000 forestry seedlings is $3.75.

APPENDIX

RESEARCH STUDIES

Leading universities have confirmed that TERRA-SORB will: reduce water stress, increase nutrient retention, replace peat moss as a moisture holding material, increase germination and in other ways improve the plant growing environment.

UNITED STATES FORESTRY SERVICE, Charles R. Venator and John C. Brissette

SUPERABSORBENTS REPRESENT A PROMISING PACKING MATERIAL FOR BARE-ROOT PINE SEEDLINGS. Loblolly pine (Pinus taeda L.) seedlings packaged in superabsorbent polymers or clay and planted within 48 hours of after 30 days cold storage were evaluated. In a test conducted in Louisiana for seedlings outplanted within 48 hours, survival of seedlings dipped in TERRA-SORB had the highest survival, 84.0 percent. The clay slurry treatment survival was 49.0 percent. In a Mississippi test, seedlings stored for thirty days in cold storage had the highest survival when treated with TERRA-SORB 1000, an experimental TERRA-SORB formulation. Survival was 94.5 percent as compared with a clay slurry control group survival of 57.0 percent.

As pointed out in the study, "Successful establishment and good early growth of outplanted seedlings are important elements in any reforestation program. The increasing use of genetically improved southern pine seedlings and high site preparation costs make planting success even more important..."

According to the study, "At least three southern forest tree nurseries have converted their pine seedling packing operations from kaolin clay slurry to a superabsorbent without any reported negative effects." The superabsorbent of choice was TERRA-SORB.

AUBURN UNIVERSITY, Dr. Frederick B. Perry

TERRA-SORB CAN BE EFFECTIVELY ADDED TO PINE BARK MEDIA TO REDUCE WATER STRESS AND INCREASE NUTRIENT RETENTION. Four rates of TERRA-SORB and a control were used on an all pine bark medium. Plastic containers were filled with unamended pine bark, or pine bark medium plus 1, 2, 3 or 4 pounds of TERRA-SORB per cubic yard. Pots were fertilized from one to five times using a 200 ppm N, P, K, soluble fertilizer from a 20-20-20

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source.

The weight of the containers at field capacity increased the first day of watering by 41, 85, 117 and 131 percent (figures correspond to the amount of TERRA-SORB added to the media). A subsequent test showed an increase of 19, 50, 66 and 70 percent. The difference in percentage is attributed to the bark not being at moisture equilibrium during the first test.

The use of TERRA-SORB to enhance the water holding capacity also increased the nutrient holding capacity of the pine bark medium. Soil nitrogen increased 3, 6 and 9 percent as the weight of TERRA-SORB increased from one to three pounds per cubic yard. Generally the nitrogen content increased by one percent with subsequent fertilizer applications.

UNIVERSITY OF GEORGIA, Dr. Vivian Munday

TERRA-SORB INCREASED GERMINATION, INCREASED THE WATER HOLDING CAPACITY AND REDUCED WATERING REQUIREMENTS OF PLANTS GROWN IN A SOILLESS GROWING MEDIA (Metro-Mix 300). Phaseolus volgaris, "Topcrop bushbean", was chosen as the test plant because it has a large transpiration surface area, and would, therefore, be expected to respond rapidly to changes in soil water content.

The weight of containers at field capacity increased by; 9, 18 and 36 percent as the amount of TERRA-SORB was increased from 1.2 to 2.2 to 3.3 pounds per cubic yard.

Germination increased from 48 percent (control) to 83 percent (1.3, and 2.2 pound per cubic yard rate) to 90 percent at the 3.3 pound per yard rate.

UNITED STATES DEPARTMENT OF AGRICULTURE, Dr. Stan Nemec

TERRA-SORB IS HIGHLY EFFECTIVE AS AN INOCULANT CARRIER FOR MYCORRHIZAL FUNGI. Results from tests conducted by the Department of Agriculture show that TERRA-SORB can be used as an inoculant carrier for mycorrhizae fungi. Treating plants with the fungi results in improved growth because the root structure is changed, improving the ability of the tree to obtain nutrients. Citrus trees treated in this manner show a substantial increase in extension growth and no evidence of phytotoxicity.

NORTH CAROLINA STATE UNIVERSITY, Dr. Roy Larson

PRELIMINARY STUDIES INDICATE THAT TERRA-SORB MAY INCREASE THE EFFECTIVENESS OF GROWTH REGULATORS.

VIRGINIA POLYTECHNIC INSTITUTE, Extension Division

TERRA-SORB INCREASED THE PERCENTAGE OF GREEN COVER AND RESULTED IN A 56 PERCENT INCREASE IN ROOT STRENGTH. Where aerified sod was soaked in a slurry consisting of 19 grams of TERRA-SORB per gallon of water, root strength was 3.6 kilograms per 900 square centimeters. For the same area, root strength of the control was 2.3 kilograms.

The percentage of green cover generally increased with the application of TERRA-SORB. The maximum increase was noted for sod that was washed free of soil and treated by dipping in a slurry consisting of 12 grams of TERRA-SORB per gallon of water. Green cover for the control was 53.3 percent. The TERRA-SORB treated sod had a green cover percentage of 90.7 percent.

Other reports concerning the use of TERRA-SORB, in applications which are not directly applicable to forestry and agriculture, are available on request.

CLOSING NOTE:

The objective in writing this paper has been to present the product and the technology in a clear, meaningful manner. We trust that you will find this information helpful.

Should you have questions or comments, please contact our office.

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TERRA-SORB "Super Soil Moisturizer"

INTERNATIONAL APPLICATIONS

TERRA-SORB is currently being distributed by over one hundred and fifty distributors in the United States and Canada. Although certain applications in these countries may be more cost effective than in other parts of the world, the following applications are economically justified world-wide.

AGRICULTURE

SEED COATING

All seed requires moisture to germinate. TERRA-SORB 200G, seed coating, applied by the farmer, is mixed dry with seed before planting fields. It requires no tackers, stickers or processing and with TERRA-SORB 200G, absorbing hundreds of times its weight in water, wrapped around each seed, germination is faster and a better germination rate is assured. TERRA-SORB 200G, is applied at the rate of 1 kg per 100 kgs of seed. TERRA-SORB 200G treated seed also lubricates planting equipment thereby providing more uniform seed drop at planting. It cost about $12-15.00 US to treat 100kgs of seed. Examples of cost of using TERRA-SORB 200G for cabbage and tomatoes per hectare (1.25 kg of seed) are 10-12 cents and for wheat (300 kgs of seed) $18.00 per hectare.

Application procedure:

Pour TERRA-SORB 200G directly onto seed in the hopper box, or seed bin, at the rate of one part TERRA-SORB 200G to one hundred parts of seed. Mix thoroughly with a stick or similar implement until the absorbent is well blended. Seed color after mixing should be uniformly darker. The total mixing time to treat a 50 kg bag of seed is less than a minute.

Note: Seed which has been treated with TERRA-SORB 200G shoould be stored under dry conditions as the material is hydroscopic, ie., has a affinity for moisture.

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SEED BED TRANSPLANTS

Many agricultural crops are started in seed beds and then transplanted into the field. One of the most critical periods in the life of these young, tender transplants occurs during transporting and transplanting the seedlings when water stress is likely to occur. If moisture is inadequate during this critical period, the transplant experiences stress and may never grow to produce expected yields. If a TERRA-SORB prepared gel is used as a packing media when transporting these young seedlings, and as a transplant dip prior to planting in the field, stress is reduced resulting in higher survival, reduced replants, less labor and increased yields. One kg of TERRA-SORB treats 10-12,000 seedlings and will cost $10-12.00 US.

APPLICATION PROCEDURE

Mix TERRA-SORB at the rate of one kg per 200 liters of water.

As a packing media, pour gel into the bottom of the transport container so that the roots of the seedling, which are later placed in the container, are in the gel. As the seedlings are lifted from the transport container, the TERRA-SORB gel will cling to the roots providing water reservoirs which reduce transplant shock and insure a better start.

As a dip treatment, simply dip the roots before planting.

Note: Should a tackier gel be desired, prepare the gel several hours before using the mixture. The addition of chemicals such as root stimulators, fungicides, etc., may require you to use slightly more TERRA-SORB than usual. Since many factors can alter the final absorbency of a polymer, only you can determine the optimum rate for your specific needs.

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FORESTRY

Survival is the most important factor in determining the overall effectiveness of a reforestation effort. TERRA-SORB increases survival and is one of the most important contributions to this industry in many years. Since 1978, hundreds of forest nurseries and ornamental growers have been using TERRA-SORB as a packing media and transplant dip. During the 1982 lifting and transplanting season, over a half billion seedlings were treated with TERRA-SORB. Leading forestry and commercial ornamental growers in the U.S. and other countries now use TERRA-SORB to increase survival and reduce the overall cost of reforestation.

APPLICATION PROCEDURE

Mix TERRA-SORB in water at the rate of one kg to approximately 200 liters of water to obtain a loose slurry of gel.

With bare rooted seedlings apply the gel to the roots of lifted seedlings by spraying or dipping the seedlings before wrapping for shipping, storing or transplanting.

With containerized seedlings, use the gel as a root ball dip or spray the root ball before planting the seedling and/or distribute dry TERRA-SORB into each hole at the rate of 1 to 2 grams prior to planting the seedling.

With field grown seedlings which are lifted with a root ball, dip or spray the root ball as it is lifted for transporting, and again as the seedling is planted.

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GREENHOUSE APPLICATIONS

As any greenhouse manager knows, water is a vital factor that must be properly managed in a greenhouse operation. Too little water can cause unwanted stress on plants and foul a production schedule. Too much water, caused by a poorly drained potting media, can result in improper aeration and root disease.

In designing a potting mix, the manager must determine the proper balance of materials which will hold water, while at the same time provide for adequate drainage and air pore space sufficient to ventilate and remove gases expelled from the roots.

TERRA-SORB plays an important role as an amendment to a growing media. It holds hundreds of times its weight in water. Unlike conventional potting medium absorbents, over 95% of the water absorbed by TERRA-SORB is available to the plant. Because more of the water held in the medium is available to the plant, faster root development and plant growth can be expected because growth does not slow down as much between waterings.

TERRA-SORB increases aeration of the growing media. Each tiny particle of TERRA-SORB expands to 30-40 times its size when in contact with sufficient water. This expansion pushes adjoining soil particles aside and provides additional aeration as water saturated TERRA-SORB begins to yield its water to the plant.

This unique combination of additional available moisture and increased aeration provides management a tool that insures faster root development, less water problems and a plant that requires less maintenence. Water usage can often be cut as much as 50%. Because TERRA-SORB absorbs liquid nutrients as well, leaching of chemicals is reduced thereby providing additional cost savings.

APPLICATION PROCEDURE

Mix TERRA-SORB with dry media at the rate of 1 1/2 kgs per cubic meter. When mixing apply TERRA-SORB slowly to insure even distribution. If media is moist, a premix may be necessary. Mix TERRA-SORB with a dry additive first, such as sand, bark, perlite, etc., and blend thoroughly. Mix the premix with remaining media ingredients. Amended media may be steam sterilzed.

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LANDSCAPING

Use of TERRA-SORB in landscaping was the fastest growing use of our technology in the beginning years of our business. This was because landscape materials always go into stress when transplanted and often do not recieve the care given them in the nursery. Landscapers were quick to realize the benefits of extending water management during and after installation of plant materials. Landscape materials treated with TERRA-SORB can frequently go two to three times as long between irrigations. Where TERRA-SORB is used, stress is reduced and the cost of replanting lost materials is cut drastically.

Think of TERRA-SORB particles as super effective little sponges which will hold many times their weight in water. The material may be broadcast into the hole before transplanting shrubs and trees. It may be broadcast over an area before laying grass or worked into the soil of a newly prepared flower bed or turf green. In hydroseeding, spraying TERRA-SORB keeps moisture on top of the ground where the seed is and provides for faster germination and a better germination rate. Today landscape architects and contractors in America, Canada, United Kingdom, Saudi Arabia, Italy and many other countries specify the use of TERRA-SORB in landscaping projects.

APPLICATION PROCEDURE

Mix TERRA-SORB thoroughly into planting soil mix used as a backfill at the rate of 1 1/2 kgs per cubic meter.

In transplanting containerized or balled materials, broadcast TERRA-SORB evenly throughout the hole at the rate of 1 gram per cm of root ball diameter.

In transplanting bare rooted materials dip or spray the roots with a TERRA-SORB gel before planting and backfill with amended planting soil mix.

When laying new grass or seeding, broadcast TERRA-SORB at a rate of 100 kgs per hectare prior to laying the grass or broadcasting seed. Should extreme heat or other adverse conditions exist, the rate should be increased to 150-200 kgs per hectare.

In hydroseeding, mix TERRA-SORB in the tank along with mulch, fertilizer and seed at the rate of 100 kgs per hectare. If adverse conditions exist, ie., extreme heat, slopes, limited water supply, etc., the rate should be increased to 150-200 kgs per hectare.

Note: When dry seeding, coat the seed with TERRA-SORB 200G, seed coating, at the rate of one part TERRA-SORB 200G to one hundred parts of seed.

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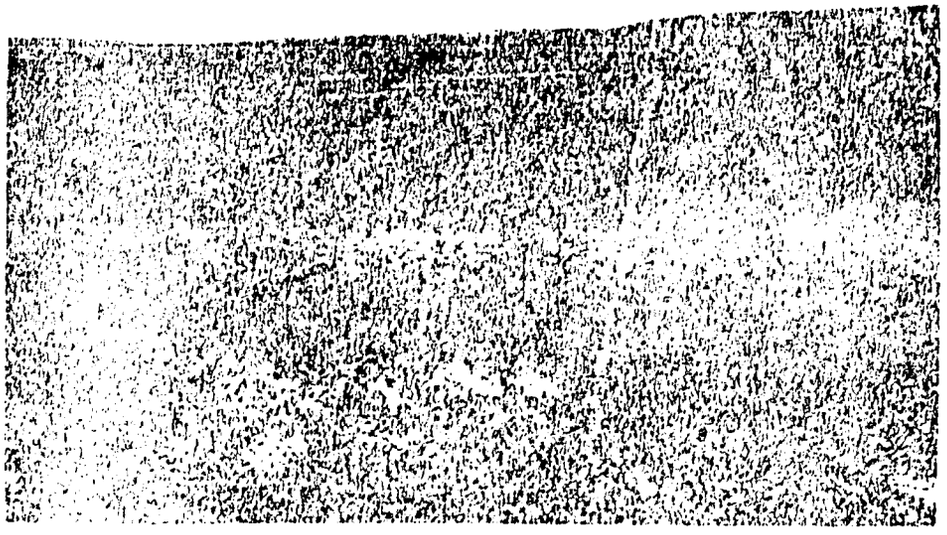
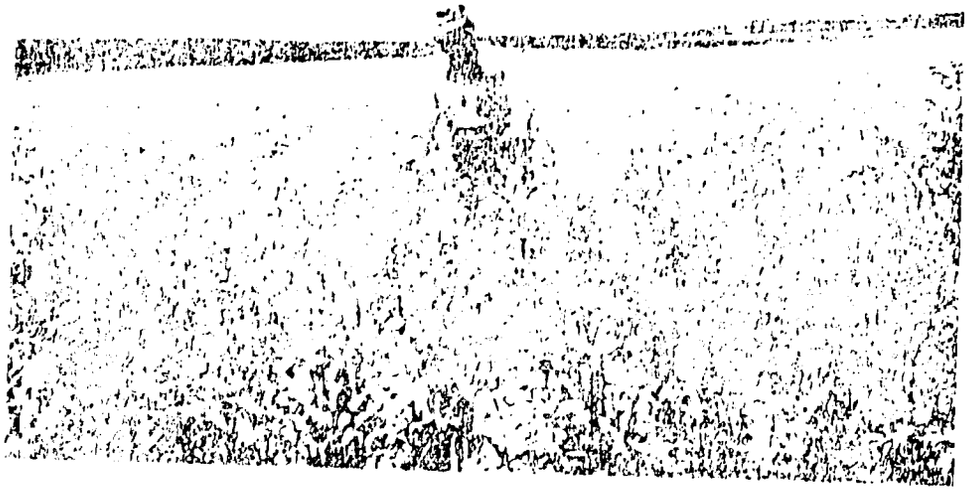
A G R I C U L T U R A L

SEED COATING



TERRA-SORB 200-G applied at the rate of 1 kg per 100 kgs of seed.

Wheat: Notice difference in appearance and height between wheat grown from seed treated with TERRA-SORB 200-G (right side) and untreated seed (left).



TOBACCO

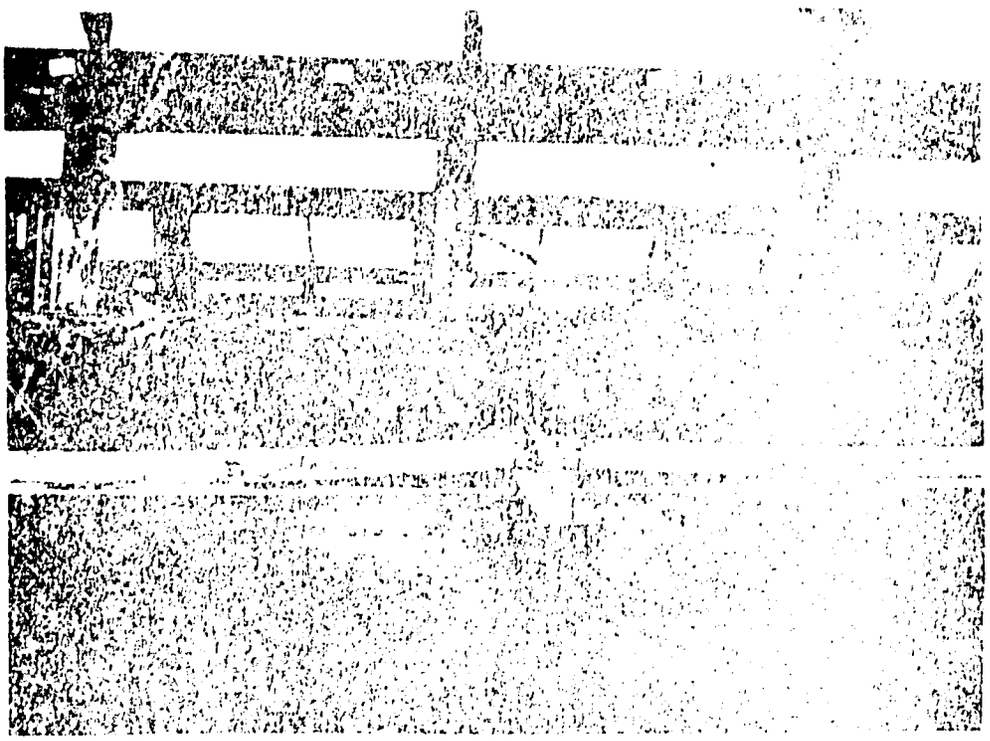
Leaf length 66 cm.

Leaf length [illegible] cm.

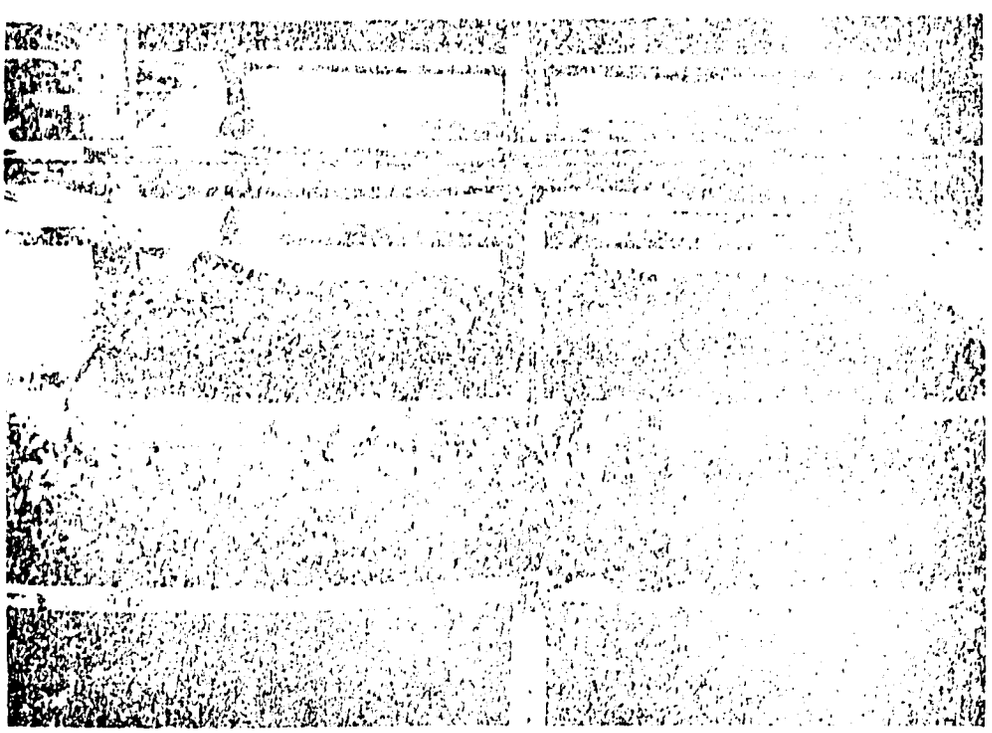
The roots of the plants on the left were dipped in TERRA-SORB gel when transplanted. Also TERRA-SORB was applied along with starter fertilizer at the rate of 4 kgs per hectare.

Average plant height 131 cm.

Average plant height 176 cm.



Plants on right were grown in medium amended with TERRA-SORB [illegible]



LANDSCAPING

TERRA-SORB broadcast before laying grass at 1 kg per 100 sq. meters. Note difference between treated (top) and untreated (bottom) sections.

TERRA-SORB used in hydromulching at 75 kgs per hectare.

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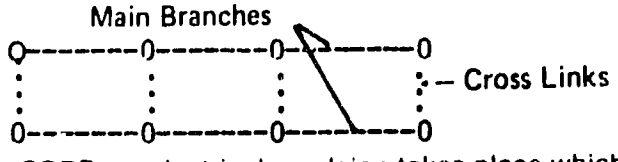
Product Bulletin (9)

TERRA–SORB – WHAT IS IT?

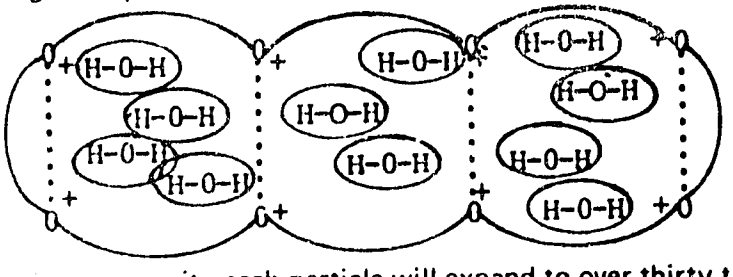
TERRA—SORB is a "super concentrated" polymer composed of a naturally occurring polymer — starch — and a synthetic polymer. Technically, TERRA–SORB is gelatinized starch-hydrolyzed polyacrylonitrile graft copolymer using potassium hydroxide. The polymer absorbs hundreds of times its weight in water – nearly all of which is plant available.

Each particle of TERRA–SORB acts like an amazingly effective sponge which is insoluble and does not change the nature of the moisture that it absorbs.

To gain an understanding of how a particle of TERRA—SORB acts to absorb moisture so efficiently, we must look at a simplified molecule of the material. Each particle or molecule has in its structure two main parallel groups of atoms which are periodically joined by connecting links as shown here.



When water is added to TERRA—SORB, an electrical repulsion takes place which causes the main branches of the molecule to repel each other, as the like poles of a magnet. As this happens, water is drawn in between the branches resulting in a rapid swelling of each particle and a rapid absorption of water as shown.



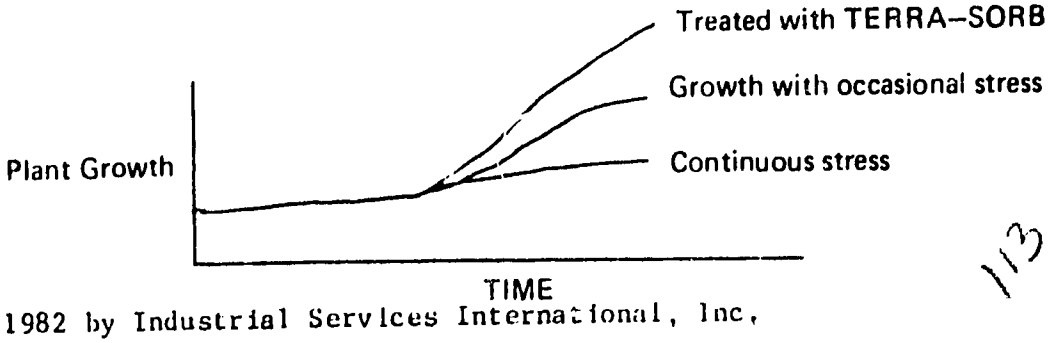
At maximum capacity each particle will expand to over thirty times its original volume.

When water evaporates or is extracted from TERRA–SORB, the material returns to an unswollen state, actually increasing the air pore space in the soil, thereby increasing aeration. When water is again introduced, TERRA–SORB will reswell as previously described.

The use of TERRA–SORB will provide the grower, shipper, retailer, farmer and other users with a highly effective, low cost method of providing plants with an optimum supply of moisture — over extended periods of time.

Since water is THE MOST IMPORTANT plant nutrient, it is little wonder that TERRA—SORB speeds root development and growth.

Most plants are watered on a schedule or when signs of wilting appear. When a plant is showing that it needs water it has long since stopped growing. The effect of maintaining an optimum moisture level is illustrated by the following graph.



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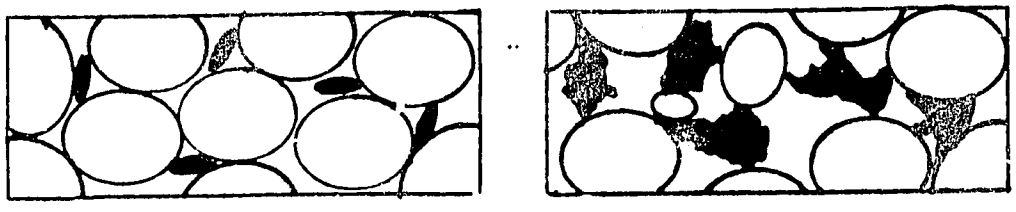
As illustrated, the growth rate is directly affected by the amount of moisture available. When TERRA—SORB is added to soil a more uniform uninterrupted growth will result since the plant is able to draw water from water-swollen TERRA—SORB moisture reservoirs.

TERRA—SORB improves aeration and drainage of the growing media. Oxygen depletion or carbon dioxide buildup in the plant root zone is harmful or fatal to the plant. When TERRA—SORB particles are present in media, they will, upon absorbing water, expand to many times their original volume. As the particles expand, they open the soil media by forcing the particles apart increasing aeration and improving drainage. At the same time, they are storing available water — this combination, high moisture along with high aeration, provides faster growth. The physical state of TERRA--SORB amended media is illustrated in the following diagram.



Terra-Sorb Black, Soil Particles White

As Terra-Sorb swells it forces soil particles apart, opening passages for air and at the same time improving moisture availability.

Because TERRA—SORB is insoluble any excess of water will freely drain through the gel particle.

Consider some of the advantages of using this material:

- Increased available water by as much as THREE TIMES!
- Greatly increased shelf life
- Increased soil aeration
- Reduced transplant shock
- Reduced resets in landscaping
- You pass the benefits of this technology on to your customers — you sell a better, more maintenance-free product
- Conservation of water and energy resources
- Faster growth
- Reduced media requirements by 10 - 15% in small containers

Plants grown with TERRA--SORB amended media reach a salable size faster. Reports of reductions of 20% to 30% in growing time until the plant is an adequate size to market have been reported. Considering that the cost of adding treated media, when finishing fern liners off into a 10" hanging basket, is about 3¢ and that the shelf life will more than double, it makes good sense to use TERRA—SORB.

For specific questions please contact your local TERRA—SORB distributor, or contact:

Industrial Services International, Inc.
P. O. Box 10834
Bradenton, FL 33507
813/792-7778

POTENTIAL APPLICATIONS FOR TERRA-SORB

1. Radioactive waste disposal.
2. Hazardous waste immobilization - rapidly gelling spilled wastes.
3. Removing excessive moisture from soils and other media.
4. Thickening agent for variety of material such as; cosmetics, paint, chemical products.
5. Oil drilling mud.
6. Absorbent towels/pads.
7. Sludge dewatering.
8. Paper coatings.
9. Pesticide application.
10. Minimizing wind drift from sprayer applied materials such as insecticides as herbicides.
11. Protein concentrating agent.
12. Replacement for conventional absorbents such as cotton.
13. Pellitizing iron ore - replacement for bentonite.
14. Filter cartridges to separate oil from water.
15. Soil stabilizing agent - minimizes wind erosion.
16. Silage preservation.
17. Core binder for metal castings.
18. Agricultural, plant/soil moisture control.

terra-sorb T.M.

Super Soil Moisturizer

Bud Heist, Owner
Heistaway Gardens
Conyers Georgia

"We were getting low germination rates in our begonia and petunia seed beds, so we tried Terra-Sorb. Not only did the percentage of germination increase tremendously, but it also reduced the time for germination. Terra-Sorb also made separation of roots in the transplanting of these tiny seedlings much easier. In the future, we are going to use Terra-Sorb in our large hanging baskets.

Overall, we believe Terra-Sorb provides for better germination, less drying out, and simply cuts down handling time."

"Having Terra-Sorb is like having a built in baby sitter for our horticultural projects. We have found that newly planted seed flats, seed beds, transplanted flowers and shrubs and all growing plants are well protected with Terra-Sorb. In addition Terra-Sorb reduces labor and saves production costs."

Sara Groves, Horticulturist for Georgia Institute of Technology, Atlanta, Georgia
Board of Directors, Bedding Plant Institute

Terra-Sorb, perhaps the most effective product in growing, has been evaluated by leading growers and landscapers in the Atlanta area. We are pleased to report their findings.

Dirk Hazeleger, President
Alpharetta Greenhouse
Alpharetta, Georgia

"We used Terra-Sorb in our 4-inch poinsettias last season and were very pleased with the results. With our overhead watering system, I don't think we could have kept them watered without it."

Doug Dorough, President
Dorough Landscaping
Lilburn, Georgia

"In our landscaping project at Paces West Condominiums we used a layer of Terra-Sorb between the ground and the sod that we laid. Our problems included many narrow spaces, extreme heat and sporadic watering. Our goal was to minimize shock to the sod and quickly establish a green cover. We definitely feel that Terra-Sorb helped us achieve these goals."

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Terra-Sorb users in other regions also report excellent results:

SOUTH CAROLINA

"We are very impressed with the substance's (Terra-Sorb) ability to absorb moisture and cling to the roots of our seedlings . . . we plan to begin using this material on all of our bare root stock in the future."

Stephen W. Cantrell, Nursery Supervisor
Champion International Corporation
Swansea, S.C.

TENNESSEE

"We dip our Bare Root evergreen liners in Terra-Sorb before we send them in the mail, or to area field nurseries to be planted straight to the field. We had no rain in the area and still the liners dipped in Terra-Sorb did not wilt before they got to the customer and stayed pretty and green before it rained."

John A. Panter, Owner
John Aubrey Panter Nursery
McMinnville, TN

FLORIDA

"Watering requirements of the Terra-Sorb containing baskets were substantially reduced (estimate 50%) . . . Terra-Sorb treated baskets exhibited no transplant shock . . . Terra-Sorb sharply reduced crop time (15 weeks vs. 20 weeks)."

Fred Haupt, President
Sunshine Plants, Inc.
Zellwood, FL

(TERRA-SORB)

- Conserves water
- Increases survival
- Maintains seed bed moisture
- A plant "baby sitter"
- Improves aeration and drainage
- Increases germination
- Increases shelf life
- Saves time and labor

For Information or to Order, Contact Your Local Distributor

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Product Bulletin (1)

TERRA–SORB IN GREENHOUSE USE

TERRA–SORB gives growers more CONTROL OF MOISTURE. Media which is amended with TERRA–SORB is more care-free than unamended media. By amending the media the following advantages have been reported: increased water capacity, increased air space in the media, improved drainage, less surface and internal "dry-outs", increased media volume in mini-containers, and slightly less nutrient use.

The degree with which the above advantages will happen depends on the growing conditions that TERRA–SORB is introduced with, such as media type, watering practices, container size, plant type, environmental conditions, etc., to say nothing of the differing greenhouse growing techniques found in the industry.

**All initial users are encouraged to perform controlled tests in a variety of applications within their operation to overcome moisture problems or increase shelf life.

PROPAGATING

Mix TERRA–SORB with dry media. Should "balling" occur, mix thoroughly and plant as usual. To mix in moist media a premix may be necessary. Mix TERRA–SORB with a dry additive first, such as sand, bark, peat, vermiculite, perlite, etc., and blend thoroughly. Mix the premix with the remaining media ingredients. Treated media should be covered if stored outdoors. Steam sterilization will not alter the effectiveness of TERRA–SORB.

TERRA–SORB amended media will yield greater germination and faster starts in sticking operations. Continuous misting can be cut back, flat "dry-outs" will decrease, and the general condition of the plant will be stronger.

CONTAINER GROWING

Mix TERRA–SORB with media at the rate of 1 - 3 lbs. per yard. TERRA–SORB should remain effective throughout the holding period of most foliage and bedding plant operations. When smaller plants are combined shortly before selling, greatly increased shelf life can result by amending the added media with TERRA–SORB. Ornamental growers benefit most in bare root shipping and planting and, in amended sticking operations. All short-term holders will benefit through increased shelf life.

SHIPPING OF BARE ROOTS

Bare roots can be shipped in a gel of TERRA–SORB mixed with water at the rate of 1 lb. of TERRA–SORB to 20 gallons of water. Distribute the gel over the roots before shipping. Over 95% of the water absorbed is available moisture. Compared to peat moss, as an absorbent in shipping bare roots, TERRA–SORB is twice as effective in terms of available moisture by weight of water. Additionally, TERRA–SORB absorbs 40-50 times as much water as peat moss by weight. Since less water is necessary (because more is available) shippers report weight reductions up to 35%. One pound of TERRA–SORB will treat about 10,000 seedlings. Dozens of state and private forestry nurseries now use TERRA–SORB to ship hundreds of millions of seedlings each year.

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Product Bulletin (2)

TERRA–SORB IN TRANSPLANTING

TERRA–SORB can be used to help decrease transplant recovery time and increase survival. Everything that grows requires moisture. TERRA—SORB gives the grower CONTROL over moisture beyond the nursery.

Tests show that TERRA—SORB actually improves root development in transplants. As TERRA—SORB comes in contact with water, each tiny flake of absorbent will swell to hundreds of times its weight holding water in a "reservoir" for the new transplant. When setting out B & B, balled, or containerized trees, shrubs, or other plants, sprinkle TERRA—SORB into the hole where the ball will be set at the rate of 1 oz. per foot of ball diameter. Water or mud the transplant in to insure the absorbent is fully expanded. Back fill may be treated with TERRA—SORB at the rate of 2-3 oz. per cubic foot of fill mix. This treatment will promote the growth and emergence of surface feeder roots.

Small plants may be treated by dipping the root ball (or bare root) into a gel of TERRA–SORB and water mixed at the rate of 4 oz. of TERRA–SORB per 5 gallons of water. Also TERRA–SORB may be used in watering tanks of field transplanting machines. Mix TERRA-SORB at the rate of 1 pound of absorbent to 30 gallons of water. If starter fertilizer solution is used, gel the water before adding the fertilizer. TERRA—SORB will inhibit nutrient leaching and help hold moisture around the root ball.

Some of the nation's largest landscapers use TERRA—SORB in transplanting. During the hot summer of 1980, TERRA—SORB was used throughout the country and the results and acceptance of the product has been very good. Many growers and landscapers will not set transplants without TERRA—SORB.

In vegetable and bedding plant transplants, the approximate cost of application is about $1.00 per thousand.

Finally it should be noted that sandy soils need less TERRA–SORB than soils with high organic levels. Each initial user of TERRA–SORB is encouraged to set up controlled tests of the absorbent to determine the most appropriate rate to be used in his operation. For answers to specific questions you may have regarding transplanting within your operation, contact your TERRA–SORB distributor.

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Product Bulletin (3)

TERRA–SORB IN LANDSCAPING

TERRA—SORB offers the landscaper CONTROL over moisture beyond the nursery with substantial savings in water, labor, energy and equipment wear and tear. Treatment of landscape materials with TERRA—SORB during installation costs little and assures the landscaper of less resets and labor. Basically, landscape materials can go up to THREE TIMES as long without watering when treated with TERRA—SORB.

To the landscape contractor TERRA–SORB is an additional product line to boost profit margins on jobs and to give the contractor the "edge" on those jobs that are bid with full knowledge of impending moisture problems.

TRANSPLANTING

Broadcast TERRA–SORB into the hole before setting the ball at the rate of 1 - 2 oz. per foot of ball diameter. Water or mud the transplant in to insure the absorbent is fully expanded.

Back fill may be treated with TERRA–SORB at the rate of 2 - 3 oz. per cubic foot of fill material. This treatment will promote the growth and emergence of surface feeder roots.

SODDING

Broadcast TERRA–SORB before laying sod at the rate of 350 to 750 square feet per pound. In extreme conditions rake TERRA–SORB into the top 3 - 4" of ground at the rate of 1 lb. per 200 to 300 square feet.

SEEDING NEW LAWNS AND TURF

When using TERRA—SORB in seeding new lawns, mix TERRA—SORB with dry seed at the rate of 1 lb. per 50 - 100 lbs. of seed. Water the seeded area in as usual. Seed will germinate faster and the germination rate will increase because of the additional moisture available to the seed.

HYDROMULCHING AND HYDROSEEDING

Add TERRA–SORB into holding tanks along with mulch, seed and fertilizer at the rate of 20 to 80 lbs. per acre depending on water stress anticipated. At the higher rates TERRA–SORB works as a tacker and binder to help control wind and rain erosion. When using fertilizer, add TERRA–SORB <u>before</u> adding fertilizer to holding tank.

INTERIORSCAPING

Mixing TERRA—SORB into potting media or planter box — at the rate of 2-3 lbs. per cubic yard — will cut watering frequencies to one third, giving employees more time to spend on plant inspections and other routine maintenance.

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PRODUCT BULLETIN (4)
SEED COATINGS

Seed coating with moisture retaining superabsorbents is proving to be a highly effective means for reducing cost, increasing yield, and in other ways benefiting the grower. Some advantages which have been identified to date include:

- Providing more uniform and vigorous stands.
- Improving emergence.
- Providing a synergistic means of applying insecticides, fungicides, growth promoting hormones and other treatment agents to the seed.
- Increasing the survivability of seedlings.

The application of a small amount of TERRA–SORB results in a remarkable increase in the level of moisture that will be immediately available to the seed and the emerging plant. When a seed that has been coated with TERRA–SORB is irrigated, the coating swells and expands, providing a "placental" gel around the seed. Up to 95 percent of the moisture contained in the gel is available to the developing plant. Resistance to drought is provided by the moisture envelope.

Insecticides, fungicides, growth promoting hormones and other such materials can be applied to the seed along with TERRA–SORB. The formation of the gel layer reduces the tendency of these materials to leach into the soil, thereby increasing their effectiveness.

SEED COATING DESCRIPTION

It is impractical to establish any coating procedure that is ideally suited to all seed forms. Rather than providing a specific procedure we have established the following guidelines concerning the coating of seeds with TERRA–SORB. *

To coat seeds with our special seed coating TERRA—SORB (TS-200G), simply mix one pound of the TERRA—SORB seed coating material with about one hundred pounds of seed. Since this form of TERRA–SORB has been prepared specifically for seed coating there is no need for tackifiers or other additives. The coated seed will not stick together, even under high humidity conditions. TERRA–SORB 200G is free flowing. It will not clog seeding equipment.

Seeds can also be coated with flake or powder forms of TERRA—SORB as follows:

1. Add seed to a clean, dry mixing vessel.
2. If necessary, add a slight amount of an adhesive material such as DuPont Spreader Sticker (diluted according to label directions for use with seed disinfectants), or water to the seed, while mixing, to promote adhesion of the TERRA–SORB.

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3. Gradually add approximately one pound of TERRA–SORB per one hundred pounds of seed. Other additives such as fungicides may be added at this time.

4. Continue mixing until seeds are uniformly coated, then screen the seed mixture to remove excess material.

5. Dry the seed and store in a dry, moisture proof container.

* We recommend conducting a trial run using a small quantity of seed prior to conducting a full scale coating procedure.

OTHER SUGGESTIONS

For certain applications, such as with grass seed, TERRA–SORB can be added directly to the spreader and mixed with the seed in a dry form. One pound of TERRA–SORB is normally adequate for fifty pounds of seed.

Once seedlings have been established and are ready for transplant, shock can be greatly reduced by dipping the roots in a dilute TERRA–SORB gel.

Prior to shipping, dip roots in a TERRA–SORB gel mixture to provide a moisture reservoir while in transit and storage.

COST

The cost of using TERRA–SORB will add approximately five dollars to the cost of one hundred pounds of seed.

QUESTIONS

We welcome your questions or comments and expect to hear from you soon.

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Product Bulletin (5)

QUESTIONS MOST ASKED ABOUT TERRA–SORB

1. WHAT IS TERRA–SORB?
   TERRA–SORB is a super concentrated absorbent capable of absorbing hundreds of times its weight in plant available moisture.

2. AS AN ABSORBENT, IS TERRA–SORB better than peat moss?
   TERRA–SORB absorbs over fifty times as much as peat moss by weight. Over 95% of moisture absorbed is plant available moisture as compared to only 40 - 50% of available moisture absorbed by peat moss.

3. Does TERRA–SORB change the nature of the moisture it absorbs?
   NO. TERRA–SORB is insoluble. TERRA–SORB simply absorbs moisture and overcomes gravitational pull storing the moisture in plant available form.

4. DOES TERRA–SORB ALTER pH?
   NO. TERRA–SORB is neutral and works over a pH range of 4 to 14.

5. WHAT IS THE EXPANSION RATE OF TERRA–SORB?
   The expansion rate is between 25 and 30 times its size in seconds.

6. DOES TERRA–SORB CAUSE OVERWATERING AND ROOT ROT?
   NO. TERRA–SORB improves aeration and drainage of the growing media. As TERRA–SORB particles expand they open the soil media by forcing the particles apart, increasing aeration and improving drainage.

7. DOES TERRA–SORB EFFECT THE ION EXCHANGE CAPACITY OF THE MEDIA?
   YES. Tests show TERRA—SORB promotes ionic exchange.

8. HOW LONG DOES TERRA–SORB REMAIN EFFECTIVE?
   The effective in-soil life of TERRA–SORB depends on such factors as soil acidity and alkalinity (pH), mineral content, soil micro-organisms and type of fertilizers. Typically, TERRA–SORB remains effective for three to six months.

9. WHY IS IT THAT LESS TERRA–SORB CAN BE USED IN SANDY SOILS?
   Because the soil particles are larger and therefore provide more air space, TERRA–SORB particles can more fully expand. In sandy soil TERRA–SORB is most efficient.

10. DOES TERRA–SORB LITERATURE EXPLAIN ALL APPLICATIONS WITHIN THE GROWIN' INDUSTRY?
    NO. The applications of TERRA–SORB are limited by the imagination of the user. TERRA–SORB is an absorbent – the grower best knows where moisture is a problem in a particular situation – TERRA–SORB gives the grower a COST EFFECTIVE management tool for the control of moisture in any growing environment.

11. CAN TERRA–SORB BE USED AS A GROWING MEDIA?
    YES. TERRA–SORB is used as an alternative to agar and in fluid drilling (pregerminated seed gel planting).

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Product Bulletin (6)

TERRA–SORB IN THE FORESTRY MARKET

TERRA–SORB is one of the most cost effective innovations in forestry in years. During the past twenty years much has been done in the industry to ensure germination and quality of forest seed. Millions of dollars are spent yearly in the development of better seed and more seedling production. TERRA–SORB has across the board applications in the production of seedlings, transporting of bare rooted stock, and survival of outplantings.

SEED BEDS

Mix TERRA–SORB into the top 4 inches of soil at the rate of 4-6 lbs. per 100 running feet of a 4 foot wide bed. If the bed is mulched, TERRA–SORB may be used in the mulching operation at the rate of 1 lb. per 30 - 40 gallons of water in the mulching tank.

SHIPPING BARE ROOTS

Bare roots can be shipped in a gel of TERRA–SORB mixed with water at the rate of 1 lb. of TERRA–SORB to 20 gallons of water. The gel may be pumped onto the bare roots in the packing process. At the rate of 1 lb. per 30 - 40 gallons of water, TERRA–SORB will flow through gravity feed systems with no worry of clogging. TERRA–SORB will not foul plumbing and is not as messy as clay or other shipping absorbents used today.

Bare roots shipped in standard forestry industry packs using TERRA–SORB as the absorbent will weigh as much as 35% less because more of the water absorbed is available and over 99% of the weight added to the seedling pack is water. Finally, because the root systems are coated with gel, survival will increase.

After all, the bottom line in forestry is SURVIVAL. Anything that will increase the survival rate of outplantings is sure to be greeted by the industry.

TRANSPLANTING CONTAINER GROWN ORCHARD STOCK

When establishing and resetting tree orchards use TERRA—SORB in the transplanting operation. Sprinkle a level tablespoon of TERRA–SORB into the hole where the transplant will be set for each gallon of container size. Transplant shock will decrease and starter root development will be quicker.

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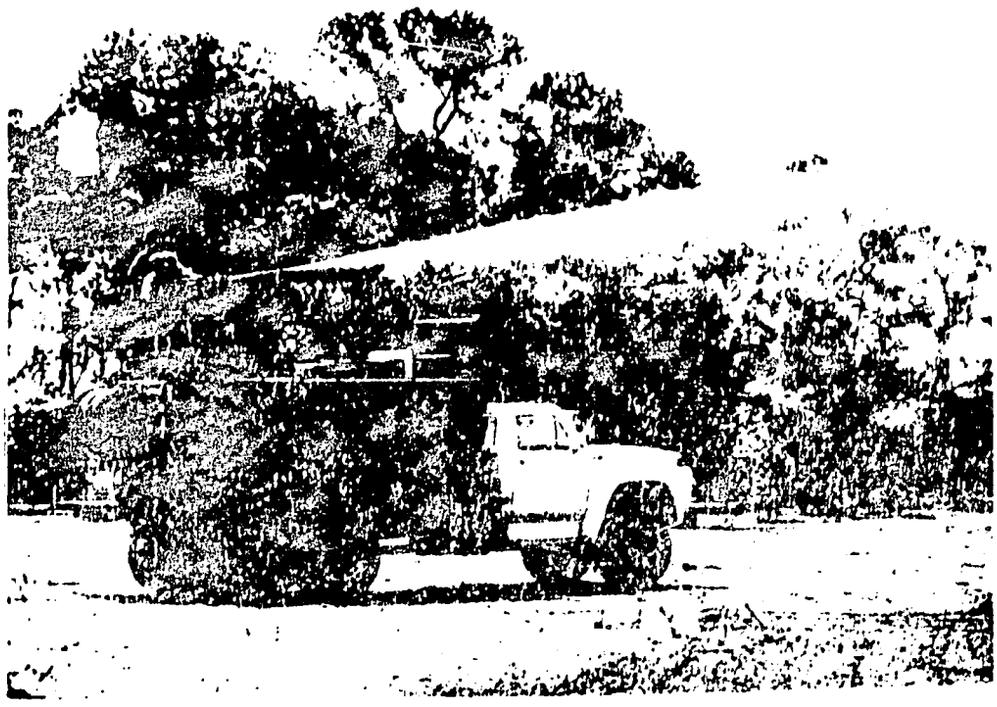
TERRA-SORB IN COMBINATION WITH HYDROMULCHING, SODDING AND SEEDING



In hydromulching/hydroseeding, TERRA-SORB is mixed with the mulch, water, seed and other additives to promote and speed germination, increase the uniformity of growth and to aid in minimizing erosion. In addition, TERRA-SORB improves fluid flow since it acts as a lubricant.

APPLICATION IN HYDROMULCHING

1. Add water mulch and other materials to the tank as usual.

2. While the tank is being agitated, gradually add the required quantity of TERRA-SORB.

3. Apply hydromulch using usual application procedure.

(Over)

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APPLICATION IN SODDING/SEEDING

1. Distribute TERRA-SORB over the area prior to sodding.
2. Lay sod or seed.
3. Water thoroughly.

APPLICATION RATES

Site Condition	Rate Per Acre
Flat, moderate rainfall	20 Pounds
Slopes, moisture stressed	50 Pounds
Steep slopes, dry site	100 Pounds

Application rates should be adjusted to suite site conditions.

TERRA-SORB is a product of Industrial Services International, Inc.

Should you have questions or comments please contact:

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P.O. BOX 10834
BRADENTON, FLORIDA 33507

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PRODUCT BULLETIN (4)

TERRA-SORB 200G

SUPER SEED MOISTURIZER

FOR

SEED COATING

- Improves germination
- Promotes faster growth
- Increases yield
- Provides more uniform stands
- Lubricates planting equipment
- Saves time and money

HOW IT WORKS:

Moisture absorbing particles in TERRA-SORB 200G expand as they draw moisture from water or humid air in the soil. In expanding, they form a gel reservoir at the seed surface. Moisture held by the gel softens seed tissues promoting rapid germination. Plants grow faster because moisture is readily available to the seedling.

Please note that TERRA-SORB 200G is not a fertilizer.

HOW IT IS APPLIED:

Simply mix TERRA-SORB 200G powder with dry seed in the ratio of one pound per hundred pounds of seed. It is ideal for hopper box application. Because TERRA-SORB 200G contains graphite, it lubricates planting machinery, maximizing planting efficiency.

RESULTS:

Yields with wheat, oats, sunflowers and other food crops have been increased by 12% to 15%.

Yields with soybeans have increased by up to 26%.

Mr. Leo Necaise of Dogwood Acres Nursery in Hope Mills, North Carolina states, "...I used some of the TERRA-SORB 200G product in sowing some Kentucky 31 Tall Fescue recently. The results were certainly pleasing and more than I expected. The seed germinated a lot faster and took hold sooner and grew tailer." He want on to say, You can rest assured that we'll be using more of this fine product in the future. The results certainly justified the low cost involved."

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INDUSTRIAL SERVICES INTERNATIONAL, INC.

TERRA-SORB "SUPER SOIL MOISTURIZER"

INTERNATIONAL BULK PRICE SCHEDULE

JANUARY 1, 1983. (U.S.$)

NUMBER OF KILOGRAMS	COST PER KG.* TERRA-SORB	TERRA-SORB 200G
UP TO 250	8.80	9.99
251 TO 500	6.60	8.23
501 TO 1000	5.94	7.57
1001 TO 2500	5.70	7.27
2501 TO 5000	5.42	6.98
5001 TO 7500	5.15	6.70
7501 TO 10000	4.99	6.50
10001 TO 18000	4.89	6.37
OVER 18000	CONTACT US FOR QUOTE	
PACKAGING SIZE IN BOXES	25KG	34KG

TERMS: *$250.00 PER ORDER EXPORT DOCUMENTATION FEE.

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TERRA-SORB SPECIFICATION GUIDE FOR LANDSCAPE ARCHITECTS

I. TREES AND SHRUBS

	High	Med	Low	High	Med	Low
	AMOUNT IN OUNCES				COST(1)	
1 gallon	1	3/4	1/2	.28	.21	.14
3 gallon	2	1 1/2	1	.56	.42	.28
5 gallon	2 1/2	1 3/4	1 1/4	.70	.49	.35
7 gallon	3	2	1 1/2	.83	.56	.42
15 gallon	6	4	3	1.67	1.12	.83
24" box	16	12	6	4.44	3.33	1.67
30" box	24	18	9	6.66	5.00	2.50
36" box	30	22	12	8.33	6.24	3.12
42" box	42	32	16	11.66	8.88	4.44
48" box	54	40	20	14.99	11.24	5.62

METHOD

Distribute evenly throughout the pit or amend backfill. Plant and water-in thoroughly.

II. SODDING, GRASSING AND HYDROMULCHING

	POUNDS PER 1000 SQ.FT.			COST(1) PER SQ.YD.		
Sodding, Seeding & Hydromulching	3	1 1/2	1/2	.12	.06	.02

METHOD

Broadcast before sodding or seeding, or include in tank along with mulch in hydromulching.

III. TERRA-SORB 200G, SEEDCOATING

		COST(1)
Grassing (Dry Broadcasting)	ONE LB PER 100LBS OF SEED	9.00

METHOD

Mix dry with seed just prior to broadcasting. No tackers are necessary.

(1) Price based upon the suggested distributor selling price as of January 1983.

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(continued on back)

1.0 MATERIAL SPECIFICATIONS

1.1 Physical Structure - Brown, flake material resembling sawdust in appearance and texture.

1.2 Absorption - Distilled water/1% saline water. 200/115 times dry weight.

1.3 Absorption Rate - 80% absorption in 60 seconds - balance in one hour.

1.4 Efficacy - Proven highly effective over three years by leading universities, landscapers and growers.

1.5 Composition - Ingredients: 100% active ingredients comprised of hydrolyzed starch polyacrylonitrile coplymer using potassium hydroxide.

1.6 Subject to biodegradation - Effective life in soil typically six months to over one year.

1.7 Product Safety - Necessary precautions in dealing with chemicals as recommendated, ie., dust masks in windy conditions, do not permit to come in contact with open cuts, etc. No evidence of any hazards to personnel have been reported.

UNIVERSITIES ATTESTING TO EFFICACY

OKLAHOMA STATE UNIVERSITY

VIRGINIA POLYTECHNIC INSTITUTE

UNIVERSITY OF GEORGIA

UNIVERSITY OF KENTUCKY

AUBURN UNIVERSITY

NORTH CAROLINA STATE UNIVERSITY

TEXAS A&M UNIVERSITY AGRICULTURAL EXTENSION SERVICE

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FORESTRY AND ORNAMENTAL USERS

We have compiled a list of TERRA-SORB users who apply the material in a dip treatment when transplanting into the field or potting up, and/or as a packing media for bare root shipments. Please call these individuals concerning their results with TERRA-SORB.

FOREST TREE NURSERIES

Mr. David Fisher, Kentucky Dam Nursery, Gilbertsville, KY., 502/362-8331. Has used TERRA-SORB since 1980 on all seedlings shipped from this nursery.

Mr. Tony Simms, Columbia State Nursery, La. Dept. of Forestry, Columbia, LA., 318/649-7463. Used TERRA-SORB on all seedlings shipped from this nursery since 1981.

Mr. Arthur R. Guthas, Hiwassee Land Company (Bowaters International), Chatsworth, GA, 404/334-2422. Has used TERRA-SORB since 1981 for all seedlings shipped from the nursery.

Mr. James H. Hill, Hiwassee Land Company, Calhoun, TN., 615/336-2211. Has used TERRA-SORB since 1980 on all seedlings shipped from the nursery.

ORNAMENTAL GROWERS

Mr. Rex Whitehill, Mid Western Nursery, Mt. Arbor Division, Shenaboah, IA., 712/246-4250. Has used TERRA-SORB since 1980 on many of their seedlings. Mid Western Nurseries is one of the largest nursery operations in the U.S. with annual sales exceeding $40,000,000. This Mid Western Nursery drop ships for Burpee Seed, and has approval for using TERRA-SORB with Burpee shipments.

Mr. Leslie R. Hobbs, Warren County Nursery, Inc., Mc Minnville, TN., 615/668-8941. Has used TERRA-SORB since 1980 as a dip treatment for field planting ornamentals and as a packing media for bare root shipments. At the Southern Nurserymen's annual trade show in August 1982, Mr. Hobbs stated he would not set anything without using TERRA-SORB. During the planting season of 1982 seedlings were field set using TERRA-SORB as a dip treatment. Although it did not rain for nearly six weeks after planting, TERRA-SORB treated seedlings survived without irrigation. Warren County Nursery is the 51st largest nursery in the country.

ORNAMENTAL GROWERS, Cont.

Mrs. Sandra Panter, John Aubrey Panter Nursery, Mc Minnville, TN., 615/668-8961. Has used TERRA-SORB since 1980 for dip treatment and shipping purposes. Mrs. Panter includes a package of TERRA-SORB, with instructions, in shipments to customers so the customer can dip seedlings as they are being planted. All seedlings shipped from this nursery are packed in TERRA-SORB.

Mr. Robert E. German, Five-M Nurseries, Inc., Lindale, TX., 214/882-3131. Ships millions of roses and crepe myrtles nationwide. Has used TERRA-SORB since 1980.

Mr. Robert H. Eastman, President, Western Maine Nurseries, Inc., Fry., MA., 207/935-2161. Has used TERRA-SORB as a packing media since 1981.

I hope this list of users will be of help to you. During the past three years the use of TERRA-SORB in bare root applications has swelled to over 400 million seedling now being treated with our product. Our product represents years of research and observation by hundreds of researchers and growers. TERRA-SORB is recognized as the most important contribution to this industry in many years. Survival rate is the bottom line in determining the total cost of a properly managed forestry operation. TERRA-SORB will enhance survival and reduce costs.

Our firm is dedicated to promoting the use of superabsorbent technology and assisting you in using this valuable technology. Should you have questions or comments do not hesitate to contact us.

James J. Quinn, President
INDUSTRIAL SERVICES INTERNATIONAL, INC.
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WHAT OTHERS SAY ABOUT TERRA-SORB

"We have been using...TERRA-SORB in planting holes for trees and shrubs and in establishing ground covers...for four years now..." Lewis Eberpacher, Landscape Architect, North Texas State University, Denton, Texas.

"...TERRA-SORB provides for better germination, less drying out, and simply cuts down handling time." Bud Heist, Heistaway Gardens, Conyers (Atlanta), Georgia

"We found that newly planted seed flats, seed beds, transplanted flowers and shrubs and all growing plants are well protected with TERRA-SORB. In addition TERRA-SORB reduces labor and saves production costs." Sara Groves, Horticulturist, Georgia Institute of Technology, Atlanta, Georgia, Board of Directors, Bedding Plant Institute.

"In our landscaping project at Paces West Condominiums we used TERRA-SORB between the ground and the sod that we laid. TERRA-SORB helped minimize shock to the sod and quickly established a green cover." Doug Dorough, President, Dorough Landscaping, Lilburn, Georgia.

"...we have decreased our watering frequency with excellent results. Until now we have tried everything from hay to mulch, with limited success. Your product is by far the best thing we have tried." Craig Nelke, Superintendent, Beth Cemetery, Woodbridge, New Jersey.

"I used...TERRA-SORB 200G recently...results were certainly pleasing and more than I expected. The seed germinated a lot faster...the results certainly justify the low cost involved." Leo Necaise, Dogwood Acres Nursery, Hope Mills, North Carolina.

"The TERRA-SORB that I have used in my bare root planting has been very effective in keeping the plants alive and fresh...I am very pleased with the results." Leslie R. Hobbs, President, Warren County Nursery, McMinnville, Tennessee.

"Last August, we transplanted 37 - 4"-8" caliper Sweet Gum trees using a 44" tree spade...weather conditions were daily highs of 100 degrees plus, and no rain. The trees were not watered for the next eight days. We were very surprised...that we had not lost a single tree...We now specify TERRA-SORB in all planting and sod laying..." Bill Miralle, Texan Landscaping Company, Houston, Texas.

"...where irrigation is a problem, the use of TERRA-SORB is invaluable." Bret Graves, Hydro Lawns, Inc., Dallas, Texas.

"We used TERRA-SORB in our 4-inch Poinsettias last season and were very pleased with the results." Dirk Hazeleger, President, Alpharetta Greenhouse, Alpharetta, Georgia.

WHAT RESEARCHERS SAY ABOUT TERRA-SORB

OKLAHOMA STATE UNIVERSITY
Dr. Carl E. Whitcomb and Phillip Gibson
TERRA-SORB can be used to replace peat without restricting growth.

AUBURN UNIVERSITY
Dr. Frederick B. Perry
TERRA-SORB can be effectively added to pine bark media to reduce water stress and increase nutrient retention.

UNIVERSITY OF GEORGIA
Dr. Vivian Munday
TERRA-SORB increased germination, increased the water holding capacity and reduced watering requirements of plants grown in a soilless growing media.

UNIVERSITY OF KENTUCKY
David Hensley
TERRA-SORB increased survival of maple trees by 298 percent.

VIRGINIA POLYTECHNIC INSTITUTE
TERRA-SORB increased the percentage of green cover and resulted in a 56 percent increase in root strength (turf application).

NORTH CAROLINA STATE UNIVERSITY
Dr. Roy Larson
Preliminary studies indicate that TERRA-SORB may increase the effectiveness of growth regulators.

Copies of the reports from which these statements are extracted are available from our office upon request.

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HERE ARE JUST A FEW OF OUR

TERRA-SORB FORESTRY CUSTOMERS

Weyerhaeuser Company
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U.S. Forest Service
Greenville, TN

U.S. Forest Service
White Bird, ID

BLM
Coos Bay, OR

Crown-Zellerbach
Joyce, LA

U.S. Forest Service
Priest Lake, ID

State Forestry
North Carolina

State Forestry
Texas

State Forestry
Tennessee

U.S. Forest Service
Albuquerque, NM

U.S. Forest Service
Gasquet, CA

Tom's Lumber Company
Coos Bay, OR

Superior Forestry Service
Leslie, AR

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Orleans, CA

Hiwassee Land Company
Chatsworth, GA

U.S. Forest Service
Willow Creek, CA

Mich.-Calif. Timber Co.
Camino, CA

St. Regis
Libby, MT

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Upper Lake, CA

Tom Benedict
McKinleyville, CA

Nekoosa Paper Co.
Port Edwards, WI

State Forestry
Missouri

State Forestry
North Carolina

State Forestry
Kentucky

U.S. Forest Service
Willows, CA

Boise Cascade Corp.
Medford, OR

Oregon State Forestry
The Dalles, OR

Crouch Forestry Services
Wilburton, OK

U.S. Forest Service
Aurora, MN

Hiwassee Land Company
Calhoun, TN

SECTION IV

Venator, C.R. and J.C. Brissette. undated. The Effectiveness of Superabsorbent Materials for Maintaining Southern Pine Seedlings Diring Cold Storage. USDA/FS Southern Forest Expirment Station.

THE EFFECTIVENESS OF SUPERABSORBENT MATERIALS [1/] FOR MAINTAINING SOUTHERN PINE SEEDLINGS DURING COLD STORAGE

by

Charles R. Venator and John C. Brissette [2/]

Abstract.--First year survival and growth of loblolly pine (*Pinus taeda* L.) seedlings packaged with seven different superabsorbent polymers, and planted within 48 hours or after 30 days cold storage, were evaluated on a Mississippi and Louisiana site. Differences in survival were significant at the Mississippi site with several superabsorbent treatments being superior to the clay slurry control. Total height differences among treatments were not significant at either the Mississippi or Louisiana site.

1/ The use of trade, firm, or corporation names of materials is for the reader's information and convenience. Such use does not constitute official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

2/ Authors are Research Plant Physiologist, Southern Forest Experiment Station, Pineville, Louisiana and Nursery and Tree Improvement Specialist, State and Private Forestry, Jackson, Mississippi, respectively.

INTRODUCTION

Successful establishment and good early growth of outplanted seedlings are important elements in any reforestation program. The increasing use of genetically improved southern pine seedlings and high site preparation costs make planting success even more imporant. It is essential, then, that seedlings begin root regeneration and height growth as quickly as possible.

The method of seedling packing and storage following lifting is likely to influence the survival and growth of pine seedlings. Many southern nurseries pack seedlings in Kraft-polyethylene bags. Just before the bags are sealed, many nurserymen spray the seedling roots with a kaolin clay slurry to help maintain a moist root surface and provide protection from exposure. This process is felt to be superior to the Forest Service bale which has been used for many years and is still used in some areas.

In 1973, a research team at the USDA Northern Regional Research Center discovered that a starch-poly-acrylonitrile polymer was capable of absorbing up to 300 times its weight in water. Since this product (commonly called superabsorbents) has been in the public domain, it has been tested for several uses in agriculture and related disciplines. Among the potential uses are seed coatings, soil amendments, rooting media, and root coatings to retard drying (Doane and Mayberry 1979, Copley 1980).

Superabsorbents are used at some forest tree nurseries as a root coating to prevent drying. However, the effects of superabsorbents on seedling survival and growth have not been reported in detail. In a North Carolina study, seedlings dipped in a superabsorbent immediately prior to outplanting did not survive as well as seedlings dipped in water or clay slurry (Goodwin 1982).

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Superabsorbents are produced in several formulations by various manufacturers. Differences among superabsorbents are primarily in the base material and in their texture. Finer textured materials generally have greater water holding capacity.

The objective of this study was to examine the effects of several different superabsorbents used in seedling packaging on survival and growth after a period of cold storage.

MATERIALS AND METHODS

In mid-January 1981, seven water absorbing substrates were mixed at the W. W. Ashe Nursery in Mississippi according to the instructions supplied by their respective manufacturers. The superabsorbents used were of various textures from a coarse, sawdust-like material to a flour-like powder. Five of the absorbents were starch based, two were synthetic based. Bundles of 50 loblolly pine (Pinus taeda L.) seedlings were collected from a single seed lot that had been processed normally on a grading table. Seedlings were graded to Wakeley's grades 1 and 2. These seedlings were then hand dipped into one of the water absorbing substrates and packed inside a Kraft-polyethylene bag. As a control, graded seedlings operationally sprayed with clay slurry and then bagged were used. Separate groups of treatments were planted within 48 hours after lifting at sandy loam sites on Erambert Seed Orchard in Brooklyn, Mississippi and the J. K. Johnson Tract of the Palustris Experimental Forest in central Louisiana. In addition, two groups of treatments were packaged and stored at 34°F for 30 days prior to outplanting at the same planting sites. The seedlings were planted in four complete blocks of randomized row plots. Each plot consisted of 50 seedlings spaced two feet within the row. The individual rows were also spaced at two feet. The seedlings were hand planted using dibbles.

RESULTS AND DISCUSSION

Survival

Differences in first year survival among treatments were statistically significant at the Mississippi planting site but not in Louisiana. At the Johnson Tract in Louisiana, the trend was for better survival among seedlings packed with some of the superabsorbents (table 1). With no storage, the best survival was observed for seedlings packed in Terra-Sorb 200 and ES 148 fine. Survival of these two treatments was uniform throughout the four blocks. However, the remaining treatments had highly variable results as indicated by the very high standard errors associated with the treatment means. The same problem was observed for seedlings stored 30 days. Terra-Sorb 200, 201, 250, and Water-Lock B-100 had high survival rates and relatively low standard errors of the means. The remaining treatments had high standard errors associated with their means.

At the Erambert Seed Orchard site in Mississippi, seedlings treated with Terra-Sorb 1000, ES 148 20 mesh, and Water-Lock B-100 had significantly better survival, regardless if stored or planted within 48 hours (table 2). Clay slurry, Terra-Sorb 200, and Terra-Sorb 201 treatments gave the poorest survival, with significant reductions in survival of seedlings stored 30 days versus those planted within 48 hours. Survival of seedlings treated with Terra-Sorb 250 was better after 30-day storage than without storage.

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That statistically significant differences were detected among treatments planted in Mississippi but not in Louisiana can be attributed to differences in variation of survival at the two sites. The standard error of the mean of each treatments was much lower for the Mississippi planting than the Louisiana planting. High variability of the standard errors reflects a wider range in percent survival among individual plots of each treatment, and consequently a lack of statistical significance among the means of the Louisiana data.

At the Louisiana site, poor survival was often associated with individual row plots. This is illustrated by the plot survival data for Terra-Sorb 1000 stored 30 days. This was the best treatment in Mississippi averaging 94.5 percent survival, but in Louisiana the 4 plots had 82, 96, 86 and 6 percent survival, respectively. Other treatments showed similar trends which raise suspicion that some factor other than drought stress, perhaps planting technique, was responsible for low survival of individual plots.

Height Growth

There were no statistically significant differences in first year total height among the treatments planted at each site, whether the seedlings were planted within 48 hours or stored for 30 days. Mean heights of treatments ranged from 19.2 cm to 25.9 cm at the Louisiana planting site (table 3). Seedling planted without storage averaged only 0.4 cm taller than those planted after 30 days storage. At the Mississippi planting site, treatment means ranged from 25.4 cm to 31.7 cm tall (table 4). The mean of seedlings planted within 48 hours was 1.1 cm greater than the mean height of seedlings planted after 30 days storage. Better height growth was expected from seedlings planted at the Mississippi site as it is more productive than the Louisiana site used in this study.

CONCLUSIONS

The survival results of this study indicate that some superabsorbents are effective root packing media for maintaining bare-root seedlings, either for prompt planting or for holding in cold storage up to 30 days storage. Those superabsorbents that were best were the finer textured materials which apparently have greater water holding capacity.

Based on one year results, superabsorbents do not appear to offer any growth advantages over treatment with clay slurry. However, there do not appear to be any negative effects of superabsorbents on seedling growth either. At least three southern forest tree nurseries have converted their pine seedling pack. operations from kaolin clay slurry to a superabsorbent without any reported negative effects.

Of course, seedlings packed in Kraft-polyethylene bags with superabsorbents, as with clay slurry, must be kept in cold storage between 1/2° C and 5° C until they are planted.

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Although we are unable to specify the best superabsorbent for seedling packaging, we feel that they represent a promising packing material for bare-root pine seedlings.

Table 1.--Percent survival of loblolly seedlings root dipped with various water absorbents prior to outplanting in central Louisiana in January and February 1981. The seedlings were checked for survival in December 1981. Fifty seedlings were planted in each plot. Differences among the means were not statistically significant at the $P < 0.05$ level.

Treatments	Blocks 1	2	3	4	$\bar{x} \pm$ S.E.
	% survival				
Outplanted within 48 hours					
Terra-Sorb 200	86	84	84	82	84.0 ± 1.6
Terra-Sorb 201	90	88	78	48	76.0 ± 19.3
Terra-Sorb 250	88	78	22	86	68.5 ± 31.3
Terra-Sorb 1000	94	12	10	94	52.5 ± 47.9
ES 148, fine	78	62	88	78	76.5 ± 10.8
ES 148, 20 mesh	64	90	18	82	63.5 ± 32.2
Water-Lock B-100	86	2	54	42	46.0 ± 34.7
Kaolin slurry	72	76	20	28	49.0 ± 29.1
Stored for 30 days					
Terra-Sorb 200	66	78	84	62	72.5 ± 10.2
Terra-Sorb 201	92	92	80	88	88.0 ± 5.7
Terra-Sorb 250	68	84	94	90	84.0 ± 11.4
Terra-Sorb 1000	82	96	86	6	67.5 ± 41.4
ES-148 fine	18	12	86	38	38.5 ± 33.6
ES-148, 20 mesh	14	72	78	64	57.0 ± 29.2
Water-Lock B-100	90	70	60	82	75.5 ± 13.2
Kaolin slurry	18	82	90	92	70.5 ± 35.3

Table 2.--Percent survival of loblolly seedlings root dipped with various water absorbents prior to outplanting in Mississippi in January and February 1981. The seedlings were checked for survival in December 1981. Fifty seedlings were planted in each plot. Means and standard errors followed by different letters are statistically significant at the P < 0.05 level.

Treatments	Blocks 1	2	3	4	$\bar{x}$ ± S.E.
	% survival				
Outplanted within 48 hours					
Terra-Sorb 200	82	78	86	80	81.5 ± 3.4 cd
Terra-Sorb 201	80	88	76	78	80.5 ± 5.3 cd
Terra-Sorb 250	68	82	78	76	76.0 ± 5.9 d
Terra-Sorb 1000	92	98	88	90	92.0 ± 4.3 a
ES 148, fine	84	94	94	92	91.0 ± 4.8 ab
ES 148, 20 mesh	88	90	98	94	92.5 ± 4.4 a
Water-Lock B-100	80	94	98	90	90.5 ± 7.7 ab
Kaolin slurry	72	86	88	90	84.0 ± 8.2 bc
Stored for 30 days					
Terra-Sorb 200	64	46	56	44	52.5 ± 9.3 c
Terra-Sorb 201	58	30	70	52	52.5 ± 16.8 c
Terra-Sorb 250	76	84	92	94	86.5 ± 8.2 a
Terra-Sorb 1000	88	92	98	100	94.5 ± 5.5 a
ES-148, fine	88	82	80	96	86.5 ± 7.2 a
ES-148, 20 mesh	94	100	90	94	94.5 ± 4.1 a
Water-Lock B-100	90	94	90	90	91.0 ± 2.0 a
Kaolin slurry	66	58	58	86	67.0 ± 13.2 b

Table 3.--Height growth of loblolly pine seedlings which were root dipped with various water absorbents prior to outplanting in central Louisiana in January and February 1981. The data represents the mean height of the survival seedlings from 50 tree plots in December 1981. Differences among the means were not statistically significant at the $P < 0.05$ level.

Treatments	Blocks 1	2	3	4	$\bar{x} \pm$ S.E.
	Heights in cm				
Outplanted within 48 hours					
Terra-Sorb 200	24.8	26.6	25.8	11.9	24.8 ± 2.0
Terra-Sorb 201	27.0	28.1	24.2	24.5	25.9 ± 1.9
Terra-Sorb 250	27.6	23.1	18.9	23.8	23.4 ± 3.6
Terra-Sorb 1000	27.3	15.5	20.2	26.3	22.3 ± 5.5
ES 148, fine	22.8	22.2	26.4	19.8	22.8 ± 2.7
ES 148, 20 mesh	23.3	27.7	19.0	24.3	23.6 ± 3.6
Water-Lock B-100	18.4	19.0	23.0	20.2	20.2 ± 2.0
Kaolin slurry	22.8	23.5	15.1	15.4	19.2 ± 4.6
Stored for 30 days					
Terra-Sorb 200	28.5	20.4	24.7	18.9	23.1 ± 4.4
Terra-Sorb 201	22.2	24.2	20.9	22.6	22.5 ± 1.4
Terra-Sorb 250	25.8	22.7	22.5	24.5	23.9 ± 1.6
Terra-Sorb 1000	23.1	25.6	23.2	13.0	21.2 ± 5.6
ES-148, fine	24.4	18.0	27.7	16.9	21.8 ± 5.2
ES-148, 20 mesh	18.3	18.0	25.0	20.0	20.3 ± 3.2
Water-Lock B-100	26.0	19.8	24.5	26.8	24.3 ± 3.1
Kaolin slurry	25.6	19.8	22.6	21.1	22.3 ± 2.5

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Table 4.--Height growth of loblolly pine seedlings which were root dipped with various water absorbents prior to outplanting in central Mississippi in January and February 1981. The data represents the mean height of the surviving seedlings from 50 tree plots in December 1981. Differences among the means were not statistically significant at the $P < 0.05$ level.

Treatments	Blocks 1	2	3	4	$\bar{x} \pm$ S.E.
	Height in cm				
Outplanted within 48 hours					
Terra-Sorb 200	28.6	32.9	29.0	29.7	30.1 ± 2.0
Terra-Sorb 201	29.8	29.1	29.9	33.9	30.2 ± 2.6
Terra-Sorb 250	24.8	30.2	31.2	32.4	29.7 ± 3.4
Terra-Sorb 1000	30.3	28.8	25.9	41.6	31.7 ± 6.9
ES 148, fine	27.9	29.4	24.9	32.7	28.7 ± 3.2
ES 148, 20 mesh	26.8	28.8	26.5	32.2	28.6 ± 2.6
Water-Lock B-100	30.3	31.1	31.1	31.1	30.9 ± 0.4
Kaolin slurry	25.4	24.9	27.3	25.9	25.9 ± 1.0
Stored for 30 days					
Terra-Sorb 200	25.2	29.1	24.0	31.4	27.4 ± 3.4
Terra-Sorb 201	25.2	26.6	24.7	24.9	25.4 ± 0.9
Terra-Sorb 250	27.6	27.4	28.7	33.1	29.2 ± 2.7
Terra-Sorb 1000	25.8	27.8	30.9	36.6	30.3 ± 4.7
ES 148, fine	24.3	27.1	26.7	37.1	28.8 ± 5.7
ES 148, 20 mesh	24.8	29.4	27.3	29.3	27.7 ± 2.1
Water-Lock B-100	25.2	29.8	28.6	29.2	28.2 ± 2.1
Kaolin slurry	25.7	29.2	30.3	36.4	30.4 ± 4.5

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Doane, W. M., and Mayberry, J. C. 1979. Super slurper swells "out all over" in crop, conservation plantings. Research News, SEA Agricultural Research, North Central Region NC-226, 10-15-79.

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SECTION V

Perry, F.B., Jr. undated. Effects of Terra-sorb on Water Retention, pH and Nitrogen Retention of All Pine Bark Medium. Auburn University.

Effects of Terra-Sorb on Water Retention, pH and Nitrogen Retention of an All Pine Bark Medium

Fred B. Perry, Jr.

Alabama Agricultural Experiment Station

Department of Horticulture, Auburn University, AL 36849

Nature of Work: Terra-Sorb 200 is a polymer composed of a natural starch polymer and a synthetic polymer. It acts in a medium to absorb water internally very rapidly resulting in a swelling of each particle to many times its original volume. When water is removed from the particle, the polymer returns to an unswollen state until water is introduced again.

Four rates of Terra-Sorb and a control were used on an all pine bark medium. Four-inch plastic containers were filled with unamended pine bark, or with the pine bark medium plus 1, 2, 3, or 4 pounds of Terra-Sorb per cubic yard. Pots were fertilized from one to five times using a 200 ppm N, P, K from a soluble 20-20-20 source. The volume of fertilizer solution for each fertilization was equivalent to the volume of the container. There were four replications per treatment in a complete randomized block arrangement.

The water retention effects of the added gel was determined by weight differences between pots containing the air dried medium and the weights of the same pots at field capacity. Pots containing the medium were watered, placed under mist (2.5 sec./5 min.) for 24 hours, watered again and allowed to drain 30 min. before wet weights were determined. The weight of the media without the added gel was considered the standard and added amount of water held by the Terra-Sorb amended media was calculated as a percent increase over this control. The same pots were watered the second day, drained 30 min. and percent water holding capacity again determined. Pots were then fertilizer 1, 2, 3, 4, or 5 times with 200 ppm N, P, K from a 20-20-20 source. Samples of media at each Terra-Sorb

level fertilized one to five times were dried for analysis. Soluble salts, pH and total nitrogen was determined for each.

Results and Discussion: Results indicate that Terra-Sorb gel does increase the water retention in a pine bark medium. The weight of 4 inch (10 cm) containers at field capacity increased the first day of watering by 41, 85, 117 and 131 percent. The comperative increase to pine bark only the second day was 19, 50, 66 and 70 percent (Table 1). Apparently the bark was not at complete moisture equilibrium on the first day.

The use of Terra-Sorb to enhance the water holding capacity also increases the nutrient holding capacity of an all pine bark medium. Solubridge readings increased from .15 millimkos/cm to .18 millimkos/cm on bark media amended with one to three lbs./yd.^{3} of gel respectively with little change in pH (Table 2). Soil nitrogen increased similarly for the same amended media (Table 2). The amount of nitrogen was increased 3% with one pound of gel/yd.^{3}, six percent with two pounds of gel/yd.^{3} and nine percent with three pounds of gel/yd.^{3}. Neither soluble salts nor soil nitrogen was increased in media containing gel amendments above three pounds/yd.^{3} Generally the nitrogen content of media with added gel increased about one percent with subsequent fertilizer applications.

The use of Terra-Sorb gel as an amendment to pine bark media in small pots seems to have at least two primary benefits. First, at the rate of two pounds/yd.^{3}, initial water retention was increased 85 percent over that of bark alone, and increased 50 percent over untreated bark later. Second, soluble nutrients were apparantly held in greater amounts with the increased water retention as indicated by increased solubridge readings with increased amounts of gel used. This fact is further borne out by the increased retention of nitrogen with increasing amount of gel used up to three pounds/yd.^{3}.

The use of Terra-Sorb at two - three pounds/yd.^{3} could aid both the grower and retailer of plants grown in small pots of pine bark media by reducing water stress and increasing nutrient retention in the container. As watering frequency increases so does the leaching out of soluble nutrients. The use of the gel not only increases the retention of soluble nutrients but reduces leaching of these nutrients by reducing watering intervals.

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Table 1. Effect of Terra-Sorb on Pinebark Water Holding Capacity in a 4" Pot

Lbs. Gel per $Yd.^3$	1st. Day Watering		2nd Day Watering	
	Mean Increase in g	% Increase	Mean Increase in g	% Increase
0	11.18	---------	17.1	---------
1	15.75	+41	20.4	+19
2	20.68	+85	25.6	+50
3	24.22	+117	28.4	+66
4	25.78	+131	29.0	+70

Table 2. Effect of Terra-Sorb Additive to Pinebark Media Soluble Salts 1/ pH, and a Total Nitrogen, After Fertilization

Lbs. Gel per $Yd.^3$	Solubridge Reading in Millimhos/cm	pH	Total Nitrogen	
			% in mix	% increase
0	.15	4.7	.33	---------
1	.15	4.7	.34	+3%
2	.16	4.7	.35	+6%
3	.18	4.8	.36	+9%
4	.18	4.9	.36	+9%

1/ Solubridge and pH determined on 1 soil;2 water extract.

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SECTION VI

Munday, V. undated. Effect of Tera-sorb on the Water Holding Capacity of Metro-mix 300 and on the Germination of Phaseolus vulgaris, "Toporop". SNA Nursery Research Journal-Vol. 7, No. 1.

EFFECT OF TERRA-SORB ON THE WATER HOLDING CAPACITY OF METRO-MIX 300 AND ON THE GERMINATION OF *PHASEOLUS VULGARIS* "TOPCROP"

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Abstract. TERRA-SORB 200, an organic water absorbing agent, was evaluated for its effectiveness in increasing water holding capacity and for reducing required watering of a soilless growing medium. In addition, germination percents and rates of *Phaseolus vulgaris*, "Topcrop," bush bean, with different rates of TERRA-SORB 200 were compared. Water holding capacity increased and required watering decreased with increased rates of TERRA-SORB 200 in 10 cm containers. There were similar changes in 15 cm containers at the lowest rate, but additional rates did not bring further changes. Germination improved in the 10 cm containers but not in the 15 cm with the addition of TERRA-SORB 200.

TERRA-SORB 200, an organic water absorbing agent, is designed to provide more uniform moisture conditions in plant growing media. The action of TERRA-SORB is not the same as that of wetting agents, which usually decrease the surface tension of water making it easier for the medium to absorb. TERRA-SORB is added to the medium and becomes gel-like when water is added. The water is gradually released from the gel as the surrounding environment becomes dry. By absorbing and releasing moisture in response to the changes in water concentration in the surrounding medium, TERRA-SORB might aid in preventing both over-and underwatering. Information distributed by the company indicates that it can absorb up to 200 times its weight in water and can increase the water holding capacity of the medium by up to 50 percent.

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METHODS AND MATERIALS

Eight treatments were established using Metro-Mix 300 as the basic medium. This product was chosen as fairly representative of the media used by growers in the Southeast. There were 16 replications per treatment. Three rates of TERRA-SORB 200 and a control were used for each of two container sizes. Four- and six-inch plastic containers were filled with unamended Metro-Mix 300, or with the Mix plus one half, 1 and 1½ times the recommended rate of TERRA-SORB 200 of 1.1 kg per cubic yard. Metro-Mix 300 is sold in 3 cubic-foot bags, therefore, the amount of TERRA-SORB per bag would be 130 gm at the normal rate.

Phaseolus vulgaris "Topcrop" was chosen as the test plant because it has a large amount of transpiration surface area. It would, therefore, be expected to respond rapidly to changes in soil water content. A standard weight was established as a basis for determining when to water each treatment. This was done by filling each container with an equal amount of air dry medium by weight. The containers were subirrigated until moist at the surface, then additional water was added at the top and excess allowed to drain for 30 minutes. The weight at this time was considered the weight at field capacity. Three seeds were planted in each container. It was found that wilting occurred at air dry weight in each container. Therefore, when the weight of the container decreased to 28 g above air dry weight, it was brought to 56 g above field capacity, which allowed a slight amount of leaching to occur.

A sensitive means for measuring container weight was designed. A container for each treatment was weighted to equal the weight at the lower water limit and placed in a second container at the end of a balance. Each day, plants from each treatment were placed in an empty container suspended from the opposite end. It was easily determined when water was needed. The amounts of water required and germination times and numbers were recorded daily.

TERRA-SORB, formerly distributed as Sorbex, is distributed by INDUSTRIAL SERVICES INTERNATIONAL, INC., Bradenton, Florida. Viterra 2, manufactured by Union Carbide Corp., is another readily available hydrogel. It is marketed in small quantities designed for retail sales to be used by homeowners in potting soil or garden plots. However, it has also been used by growers at the rate of 2.75 pounds (1.1 kg) per cubic yard of potting soil. It would, of course, be advantageous to both producers and retailers if a margin of safety could be provided in the event of over- or underwatering containerized plants due to inadvertant practices or unavoidable environmental conditions.

Bearee and McCollum (1) found that Viterra 2, a similar hydrogel compound, improved the available water capacity of both peat-lite and non-composted bark. In addition, aeration and drainage were improved. Chrysanthemums grown in the amended media were of better quality and had longer shelf life than control plants. Still (4) reported better growth of chrysanthemums in Viterra 2 amended soil. However, an optimum level was reached beyond which dry weight decreased. He suggested that rates lower than those recommended were equally satisfactory. Gehring (3) found that hours to wilting increased for bedding plants grown in media amended with Viterra 2, Hydrogels have been used in fluid drilling techniques as an effective means of planting pregerminated seed (2). There is relatively little information on the use of hydrogels in the germination medium.

This experiment was designed for the purpose of evaluating the effectiveness of TERRA-SORB, first, in increasing the water holding capacity of the medium; and second, in decreasing the required frequency of watering. In addition, it was of interest to compare the germination rate of seeds planted in medium with or without TERRA-SORB added.

RESULTS

The results of this study indicated that TERRA-SORB 200 does increase the water-holding capacity of this medium. The weight of 4-inch (10cm) containers at field capacity increased by 9 percent, 18 percent, and 36 percent as the rate of TERRA-SORB 200 increased (Table 1). The increase in weight of 6-inch (15 cm) containers followed a similar pattern with increased of 16, 22 and 38 percent (Table 1). The weight at the wilting point was reduced by 8 and 16 percent for the 4-inch (10 cm) and 4 and 9 percent for the 6-inch (15 cm) containers at the two higher rates of TERRA-SORB 200 (Table 1). The amount of water required was reduced for the 15 cm container by the addition of TERRA-SORB 200 at the ½ x rate; however, higher rates brought no further reduction. There was no improvement in germination. Water requirements were reduced and germination improved with increasing rates of TERRA-SORB 200 in the 10 cm containers. The improved germination resulted in a much higher proportion of small containers with 100% germination. These results are shown in Tables 2 and 3.

DISCUSSION

Perhaps one of the most interesting points brought out by this study is the change in results with change in container size. Most growers recognize the advantages of large soil volumes. However, most growers have also found that they are able to realize more dollar return per square foot of bench space by growing plants in smaller containers. In addition to the advantage of more rapid turnover, they are finding an advantage in the increasing consumer demand for less expensive, easy-to-carry small sizes. This is particularly the case when products are sold through mass merchandising outlets. Often in this type of retail situation plants suffer water stress, and the small containers provide very little safety margin. Under such circumstances, the use of TERRA-SORB 200 could

aid in preventing plant stress by helping minimize wide fluctuations in water levels of the medium. Each individual should test a small number of containers at various levels to determine the optimum rate under his conditions.

Although in this study germination was not improved in large soil volumes by the addition of TERRA-SORB 200, growers germinating seeds in small containers might benefit from its use. It would be particularly important to growers seeding directly into small containers intended for sale without transplanting. The data presented in Table 3 seem to indicate that the ½ x rate in Metro-Mix 300 is adequate. However, higher rates would be beneficial in reducing frequency of watering. Based on our results, we would suggest the addition of TERRA-SORB 200 to media used in small containers but would suggest it be used only at the ½ x rate, if at all, in larger containers.

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Table 1. Average weight of 10 cm or 15 cm pots of Metro-Mix 300 treated with various rates of TERRA-SORB 200 at field capacity and at onset of wilting of *Phaseolus vulgaris*.

Treatment **	10 cm				15 cm			
	Field capacity		Beg. wilt		Field capacity		Beg. wilt	
	Gm	% Change from control*	Gm	% Change from Control*	Gm	% Change from control*	Gm	% Change from Control*
Control	341	0	186	0	1147	0	713	0
½ x	372	9	186	0	1333	16	713	0
1 x	403	18	170.5	-8	1395	22	682	-4
1½ x	465	36	155	-16	1581	38	651	-9

*Changes significant at the .05 confidence level.

**Rates of TERRA-SORB200 per cubic yard, 1X = 1.1 Kg (2.42 lbs.).

Table 2. Average water requirement of *Phaseolus vulgaris* growing in 10 cm or 15 cm pots of Metro-Mix 300 treated with various rates of TERRA-SORB 200.

Treatment**	10 cm		15 cm	
	ml	% Change from control*	ml	% Change from control
Control	217	0	310	0
½ x	136	-37	248	-20
1 x	116	-45	248	-20
1½ x	97	-55	248	-20

*Changes significant at the .05 confidence level.

**Rates of TERRA-SORB200 per cubic yard, 1X = 1.1 Kg (2.42 lbs.).

Table 3. Average percent germination of *Phaseolus vulgaris* seeded in 10 cm or 15 cm pots of Metro-Mix 300 treated with various rates of TERRA-SORB 200.

Treatment *	10 cm	15 cm
Control	48	94
½ x	83	88
1 x	83	92
1½ x	90	92

*Rates of TERRA-SORB200 per cubic yard, 1X = 1.1 Kg (2.42 lbs.)

SECTION VII

Nemec, S. undated. Inoculation of Citrus in the Field with Visicular Arbuscular Mycorrhizal Fungi in Florida. Tropical Agriculture (in press).

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Inoculation of Citrus in the Field with Visicular Arbuscular Mycorrhizal Fungi in Florida[1**]

S. Nemec[2]

Abstract

The vesicular arbuscular mycorrhizal fungi Glomus etunicatus and G. mosseae were used to inoculate citrus by banding inoculum below seed in a seedbed experiment, and by dipping plant roots in inoculum with sticking agents in aqueous slurries in three field tests. Maximum potential plant growth was not reached with the highest inoculum level, 40,000 chlamydospores, in the seedbed test. Seedling plants dipped in slurries of inoculum containing carboxymethylcellulose, casein or gum arabic grew better than noninoculated controls. Growth of plants dipped in slurries containing G. etunicatus and four hydrogels was generally significantly better than that of their respective controls, but all controls including the control not dipped in hydrogels were infected by indigenous species. Root-dip inoculation has a practical use in nursery citrus production.

Key Words: Endomycorrhizal fungi, hydrogels, root-dip inoculation, Glomus species.

[1]This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended. Mention of a trademark or proprietary product does not constitute a guarntee by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

**This paper has been submitted for publication to Tropical Agriculture and is considered to be "In Press".

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Inoculation of Citrus in the Field with Vesicular Arbuscular Mycorrhizal Fungi in Florida

S. Nemec

Introduction

A wealth of applied and basic information has been presented on the biology of symbiotic vesicular arbuscular (VA) mycorrhizal fungi during the last decade. Because these fungi confer to the host some resistance to plant pathogens and significantly benefit the nutrient status of the plant, they have a potential application in agricultural practices. Currently, there is a strong interest by researchers in developing commercial sources of VA inoculum.

Although most studies with VA fungi have been done in greenhouse pots, an increasing number of studies have been done in the field with greenhouse-preinoculated plants or with inoculum added to plots. These field studies have shown that growth or yield of sweet gum (2), yellow poplar (23), peach (11), soybean (4, 21), corn (8), geranium (20), wheat (9), red clover (7), barley (3), and onion (14) were improved by inoculation. In addition, inoculated citrus, which is highly mycorrhizal dependent, grew significantly better than noninoculated plants in studies done in South Africa (12), California (5, 18), Illinois (10), Texas (24), and Florida (16, 22).

In most of these studies, plants or seed were inoculated by adding pot cultures of inoculum containing spores, sporocarps, infected root fragments, and extramatrical mycelium to the soil in which they were grown (2, 7, 10, 11, 12, 16, 21, 22). Hayman et al. (7) used a variation of the crude inoculum technique by fluid-drilling wet-sieved inoculum and pre-germinated seeds suspended in 4% methylcellulose into the row. Other researchers used chlamydospores to inoculate either seed or rooted cuttings (4, 6, 8, 20). Both

Hattingh and Gerdemann (7) and Diem et al. (4) obtained a growth response by pelleting seed with spores using methylcellulose and polyacrylamide gel, respectively.

Presently, it is not practical to inoculate large-scale plantings of citrus in Florida by most of the above-mentioned methods. Compared to greenhouse studies, field inoculations require large amounts of inoculum, which are presently unavailable. Furthermore, attempts to concentrate crude inoculum by wet-sieving and sucrose gradient techniques require additional time and expense; and most nurserymen do not have greenhouses in which to inoculate plants prior to planting in the field. Other practical techniques to inoculate citrus have been considered. This report describes a root-dip method that requires minimal quantities of inoculum compared to other methods, and defines additional parameters of the technique to amend soil with inoculum.

Materials and Methods

Four field tests were established with citrus seed or seedlings and inoculum of Glomus mosseae (Nicol. & Gerd.) Gerd. & Trappe, and G. etunicatus Becker and Gerd. In test I, a seedbed was established at the USDA Hiawassee Farm (Orlando) and fumigated with 2.24 kg methyl bromide/ha. Rows 1.2 m wide were established in the bed and trenches were dug along each row, 10-13 cm deep and 25-28 cm wide. Pot culture soil containing 0, 500, 1000, 2500, 5000, 10,000, 20,000, and 40,000 chlamydospores of each species was applied in 1.8-m linear replicates for each rate to the rows. Each plot for each species was a randomized complete block design with four replications per treatment. The inoculum was covered with some of the soil excavated from the trenches. About 50 sour orange (Citrus aurantium L.) seeds were planted in each replicate on March 10, 1981. This plot was fertilized monthly with a 16-0-16 granular fertilizer and growth data were collected on December 1, 1981.

Roots of greenhouse-grown nonmycorrhizal seedlings were dipped in slurries of inoculum containing sticking agents and hydrogels in the remaining three tests. In test II, Cleopatra mandarin (C. reticulata Blanco) seedlings were dipped in 2000 ml of 1% aqueous carboxymethylcellulose (CMC) amended with pot culture inoculum containing 4360 chlamydospores of G. etunicatus, and in a slurry containing 2720 G. mosseae chlamydospores. This test was set up in a citrus nursery at Avon Park, FL, April 10, 1980, in soil treated with 1,3-dichloropropene (1,3-D) at the rate of 55 liters/ha, and growth response was determined December 9, 1980.

Test III was established March 27, 1980, at Hiawassee Farm. Roots of 'Cleopatra' mandarin seedlings were dipped in 2000 ml of 4% aqueous gum arabic and 4% casein, each containing pot culture inoculum of 1600 G. mosseae chlamydospores. Plants were also dipped in 1500 ml water containing 4% gum arabic or 4% casein with 1200 G. etunicatus chlamydospores. Soil in this plot was treated with methyl bromide at the rate of 1.12 kg/ha several weeks prior to planting. Plant growth was determined in November 1980.

In test IV, four additional sticking agents were used in a test at Hiawassee Farm in April 1981. These compounds were chosen from a selection of hydrogels which includes starch-based, synthetic acrylic, and clay-based products for use in agriculture. Rough lemon (C. limon L. Blanco) seedling root systems were dipped in aqueous suspensions, with and without inoculum, containing 0.56% Terra-sorb®, 0.75% Laponite®, 0.56% Viterra-2®, and 2.5% Agra-gel®. Each slurry was made up to a volume of 7560 ml and amended with 82,500 G. etunicatus chlamydospores from pot cultures. Plant growth was measured in November 1981.

In each experiment, terminal growth was used as a measure of plant response; however, in the three experiments involving root-dip inoculation,

extension growth and stem caliper were usually taken. Extension growth was determined by measuring the length of all the branches and adding that to the height value. A noninoculated plant was always used as a control in these tests, noninoculated plants dipped in the sticking agents were usually used as controls, and a seedling preinoculated in the greenhouse was used to determine if mycorrhizal plants were effective in the sites selected. Experiments II, III, and IV were arranged in a randomized complete block design with four replicates in tests II and III and three replicates in test IV. Six seedlings were planted in each replicate. No root infection was evaluated in the first test. At the termination of each of the last three tests, mycorrhizal fungus infection was evaluated in roots. Infection was estimated in roots of plants in all treatment replicates in test III, and estimated in the remaining two tests by pooling into one sample roots from all the replicates of each treatment. Roots were examined for fungus infection by the Phillips and Hayman technique (19). The tests at Hiawassee Farm were fertilized monthly with 16-0-16. Soil was collected from all plots for mineral analysis.

Results

Height and top weight data for sour orange seedlings grown from seed planted in soil amended with inoculum levels of G. etunicatus and G. mosseae in test I were evaluated by regression analysis (Fig. 1). Linear regression for height (Fig. 1A) indicated that the lines for both G. etunicatus and G. mosseae were parallel, each indicated a gradual increase in height as rates increased. The R^2 values for G. etunicatus and G. mosseae were 0.48 and 0.31, respectively. A similar parallel relationship for top weight occurred between these two species (Fig. 1.B). The R^2 values for top weight were 0.44 for G. etunicatus and 0.58 for G. mosseae. For G. etunicatus, no inoculum level was

Fig. 1

reached beyond which no further increase in height or top weight occurred. For G. mosseae, it appeared that at 10,000 chlamydospores no additional increase in top weight was realized with additional inoculum. Although each Glomus species was inoculated in adjacent sites, sour orange seedling growth was consistently better with G. etunicatus.

In test II, terminal height of Cleo seedlings root-dipped in a CMC slurry of G. etunicatus was significantly greater than in noninoculated seedlings (Table 1). Seedlings preinoculated in the greenhouse were also taller than the control, however, extension growth of inoculated seedlings in these two treatments was not significantly different from the control. The presence of infection in roots of the noninoculated control indicated that the 1,3-D used for nematode control did not effect control of mycorrhizal fungi in this plot. Table 1

In test III, Cleo seedlings dipped in slurries of inoculum and gum arabic grew significantly better than the noninoculated control in the test with gum arabic and casein as stickers at Hiawassee Farm (Table 2). Casein appeared to be less effective in this regard than gum arabic. Stem diameter appeared to be more sensitive than terminal height as a measure of response to the treatments. The presence of infection in the control indicated that methyl bromide did not effectively control indigenous mycorrhizal fungi in the soil. Table 2

Three growth parameters were measured and compared in test IV with four hydrogel sticking agents (Table 3). Terminal height of rough lemon root-dip-inoculated with each hydrogel did not significantly differ from the height of their respective controls, nor from the noninfected and infected controls. Extension growth suggested that inoculated rough lemon in each root-dip treatment grew consistently better than the hydrogel controls; however, this was only statistically significant with Viterra-2. None of the inoculated Table 3

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treatments grew significantly better than the noninfected control. Extension growth of the preinoculated plants was significantly better than the non-inoculated treatments. Stem caliper of inoculated plants in Laponite and Viterra-2 was superior to these treatments without the fungus. Stem caliper of preinoculated seedlings was significantly greater than the seedlings in all other treatments. Infection occurred in plants of all treatments of this experiment (Table 4). Infection based on vesicle and hyphal development and percentage of infection were consistently better in the root-dip-inoculated plants than in the appropriate controls. Infection in all of the noninoculated controls indicated that methyl bromide did not completely eradicate indigenous mycorrhizal fungi. Table 4

At planting, the Hiawassee seedbed soil contained 13 ppm nitrogen (N) and 36 ppm phosphorus (P). At the end of the test, these levels were 10 and 42 ppm, respectively. The Hiawassee Farm hydrogel plot contained 27 ppm N and 46 ppm P at the beginning of the test, and 10 ppm N and 36 ppm P at the end. The Avon Park site contained 10 ppm N and 60 ppm P at the end of the test; no soil samples were collected at planting. At the beginning of the 1980 Hiawassee Farm test, the soil contained 129 ppm P; no soil analysis was made at the end of the test.

Discussion

Florida citrus nurserymen have for years sown seed outdoors early in the year in seedbed plantings. To meet the burrowing nematode certification requirements and to minimize problems of soilborne fungus pathogens, these seedbeds have been methyl bromide treated. Stunting problems arising from complete control of mycorrhizal fungi have been partially corrected in these seedbeds by applying about 2,240 kg superphosphate per ha (1 ton/acre). This practice

is based on original studies by Tucker and Anderson (25). Because of the shortage of available nursery land, many nurserymen have had to reuse seedbed land in alternate years. Re-treating this soil with P has raised the P content of the plant to levels which can inhibit mycorrhizal fungus infection in roots. Addition of mycorrhizal fungus inoculum, by banding below seed, in nursery seedbeds has generally failed to increase growth in numerous tests. (16, 17). However, two tests of this type made at Hiawassee Farm, one in this study and one in a previous one (16), have proven that this inoculation technique is effective even in soil with a low to moderate P level. In general, growth of plants inoculated with both Glomus species in this study progressively increased as inoculum level was increased.

In nursery seedbeds, inoculum banded beneath seed may be ineffective due to inhibition by high P content in plants (13). Also, the inoculum may not survive because of the time interval between application and seed germination, the inoculum may become parasitized, or it may be killed by pesticides. The technique of dipping roots in inoculum slurries may eliminate some of the problems associated with banding inoculum in the soil. The time interval between intimate contact of inoculum and a susceptible root is shortened, thus reducing the inoculum survival factor. Covering the entire root system with inoculum could result in more infection points, creating a more uniform and complete infection of the root. This inoculation procedure would be a suitable step to use between digging plants from the seedbed and transplanting to the nursery row.

The hydrogels at the rates used form a slurry with an even consistency and appear to be the safest and most economical of the stickers available. Their use did not result in phytotoxic or plant growth inhibition responses, although Laponite may have slightly inhibited infection due to its high pH.

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They have been used successfully in fluid drilling of pregerminated vegetable seed for moisture retention purposes (1). Casein, gum arabic, and CMC did not mix uniformly in slurries, and CMC in previous tests (17) at levels of 4.5 to 11% caused stunting and plant death. The inoculum levels used were the highest quantities of inoculum available for use at the time. Growth response occurred over the wide range of inocula used, but further tests need to be done to determine the optimum quantities needed.

Soil P levels were not high enough in these experiments to be considered a factor limiting infection in roots. A major factor affecting the results of these experiments was the contamination of control plant roots by indigenous species. It is unknown how much this infection affected plant growth of either the controls or the treatments. Fungus colonization of control plant roots, however, was expected in the site treated with 1,3-D, because 1,3-D is not toxic to Glomus species at low rates (15).

This study reports on a slurry root-dip technique to inoculate citrus with vesicular-arbuscular mycorrhizal fungi that may have a practical application in citrus nursery production. The root-dip technique is especially valuable since it would allow the nurseryman to inoculate only the most mycorrhizal-dependent rootstocks if he preferred, or allow him to match species with rootstocks once the most effective endomycorrhizal species have been identified and cultured. Other inoculation techniques may prove useful in the nursery industry. Fluid drilling of inoculum in the furrow with pregerminated seed may speed up the inoculation procedure, and methods to inoculate greenhouse-grown seedlings should be studied, also, in the future.

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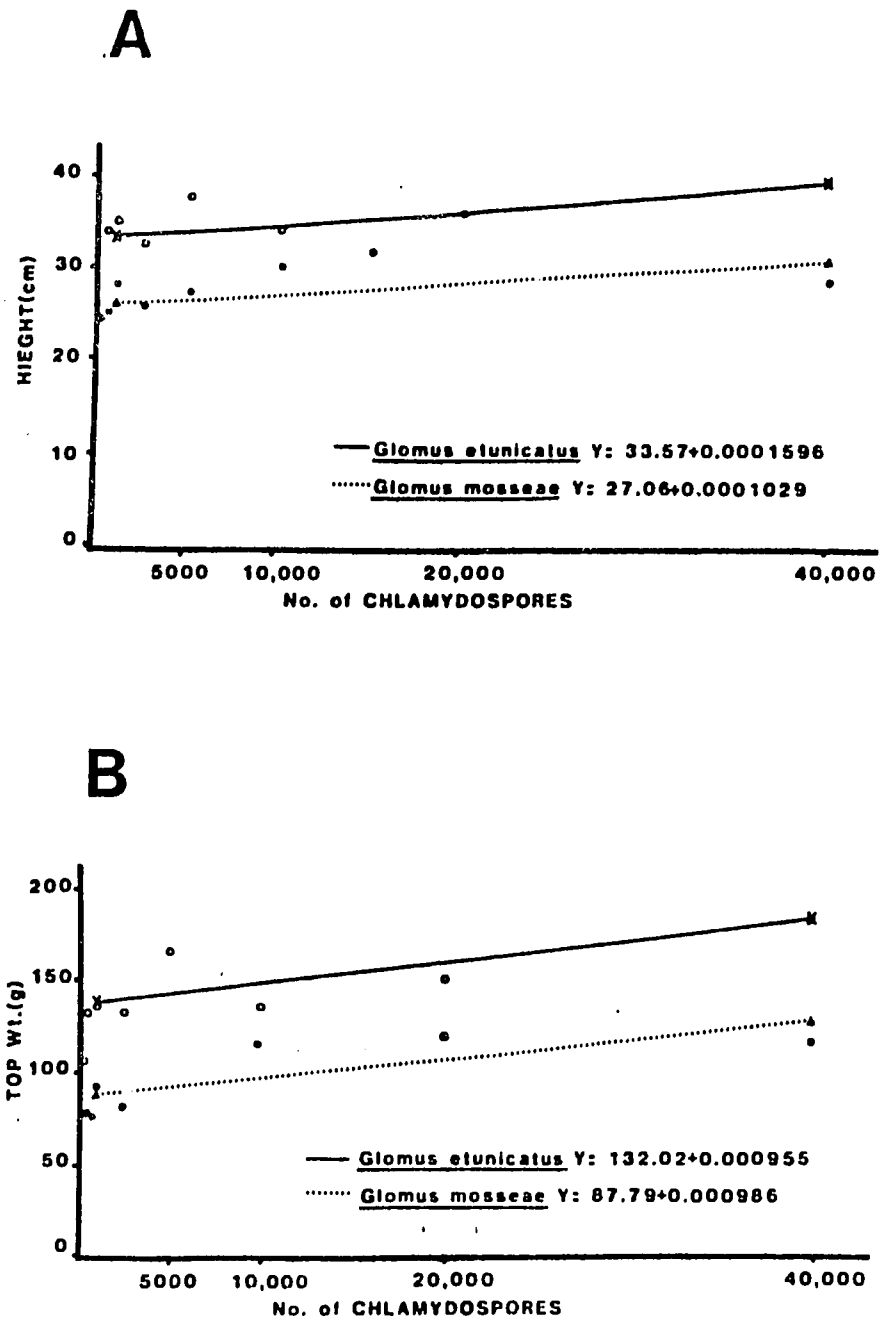

Fig. 1. A) Observed and estimated (linear regression) effect of Glomus etunicatus and G. mosseae chlamydospore number on height of sour orange citrus seedlings. B) Observed and estimated (linear regression) effect of G. etunicatus and G. mosseae chlamydospore number on top weight of sour orange seedlings. Data points are the means of eight seedling plant replicates per treatment.

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Table 1. Plant growth and fungus development in roots of Cleopatra mandarin seedlings dip-inoculated in aqueous slurries of carboxymethyl-cellulose (CMC) amended with *Glomus mosseae* and *G. etunicatus*.

Treatments[z,y]	Terminal height (cm)	Extension growth (cm)	% Roots infected with[x]		
			Vesicles	Hyphae	Fungus
CMC + *G. etunicatus*	105.3*	169.3[N.S.]	21	55	56
CMC + *G. mosseae*	95.2[N.S.]	151.8[N.S.]	-	-	-
CMC	99.4[N.S.]	190.5[N.S.]	-	-	-
G. etunicatus infected control[w]	108.7*	155.1[N.S.]	23	77	77
Noninfected control	88.1	143.8	19	66	66

[z]One percent CMC amended with soil inoculum containing 4,360 *G. etunicatus* or 2,720 *G. mosseae* chlamydospores in 2,000 ml water.

[y]Treatment means compared with noninfected control by Dunnett's test.

[x]Percentage infection evaluated in 100 root pieces/treatment.

[w]Preinoculated in a greenhouse.

Table 2. Plant growth and fungus development in roots of Cleopatra mandarin seedlings dip-inoculated in aqueous slurries of gum arabic and casein amended with *Glomus mosseae* and *G. etunicatus*.

Treatments[z,y]	Terminal height (cm)	Stem caliper (mm)	Fungus infection[x] (%)
Gum arabic + *G. etunicatus*	86.8*	11.4*	49[N.S.]
Casein + *G. etunicatus*	79.4[N.S.]	10.8[N.S.]	42[N.S.]
Gum arabic + *G. mosseae*	91.7**	11.3*	31[N.S.]
Casein + *G. mosseae*	82.9[N.S.]	11.9***	71[N.S.]
G. etunicatus-infected control[w]	93.2**	12.9***	73[N.S.]
Noninfected control	75.9	9.8	33

[z]Four percent gum arabic and casein each amended with soil inoculum containing 1600 *G. mosseae* in 2000 ml H_2O, and 1200 *G. etunicatus* chlamydospores in 1500 ml water.

[y]Treatment means compared with noninfected control by Dunnett's test.

[x]Percentage infection evaluated in 30 root pieces per replicate.

[w]Preinoculated in a greenhouse.

Table 3. Growth of rough lemon seedlings dipped in *Glomus etunicatus* (G.e.) inocula with and without hydrogel sticking agents.

Treatment	Growth parameters*		
	Terminal height (cm)	Extension growth (cm)	Stem caliper (cm)
Terra-sorb + G.e.	101.3[a]	366.0[ab]	1.44[bcde]
Terra-sorb - G.e.	100.7[a]	262.3[bc]	1.34[de]
Laponite + G.e.	105.5[a]	322.7[abc]	1.53[b]
Laponite - G.e.	96.7[a]	267.0[bc]	1.37[cde]
Viterra-2 + G.e.	102.2[a]	369.7[ab]	1.46[bcd]
Viterra-2 - G.e.	97.7[a]	225.7[c]	1.32[e]
Agra-gel + G.e.	99.6[a]	346.7[abc]	1.47[bc]
Agra-gel - G.e.	103.1[a]	282.7[bc]	1.41[bcde]
Noninfected control	107.1[a]	239.7[bc]	1.44[bcde]
G.e.-infected control[z]	108.2[a]	442.3[a]	1.67[a]

*Means sharing the same small letter in each column are not significantly different according to Duncan's Multiple Range Test at the 5% confidence level.

[z]Preinoculated in a greenhouse.

Table 4. Vesicle and hyphal development and percentage infection by vesicular arbuscular mycorrhizal fungi in rough lemon roots dipped in Glomus etunicatus (G.e.) inocula with and without hydrogel sticking agents.

Treatment	Vesicles[z]	Hyphae[z]	Infection[y] (%)
Terra-sorb + G.e.	1.34	2.21	90
Terra-sorb - G.e	0.03	0.76	45
Laponite + G.e.	0.44	1.10	63
Laponite - G.e.	0.01	0.48	21
Viterra-2 + G.e.	0.76	1.84	93
Viterra-2 - G.e.	0.40	0.51	43
Agra-gel + G.e.	0.63	1.75	87
Agra-gel - G.e.	0.01	0.34	21
Noninfected control	0.20	0.50	20
G.e.-infected control[x]	1.00	1.85	97

[z]Ratings: 0 = no vesicles nor hyphae, 1 = 1-50 vesicles or light hyphal infection, 2 = 51-100 vesicles or moderate hyphal development, and 3 = 100 + vesicles or heavy hyphal development.

[y]Percentage infection based on number of 100, 1-cm-long fibrous root pieces infected per treatment.

[x]Preinoculated in a greenhouse.

SECTION VIII

Johnson, C.R. and J.A. Menge. Jan. 15, 1982. Mycorrhizae May Save Fertilizer Dollars. American Nurseryman, pp. 85-87.

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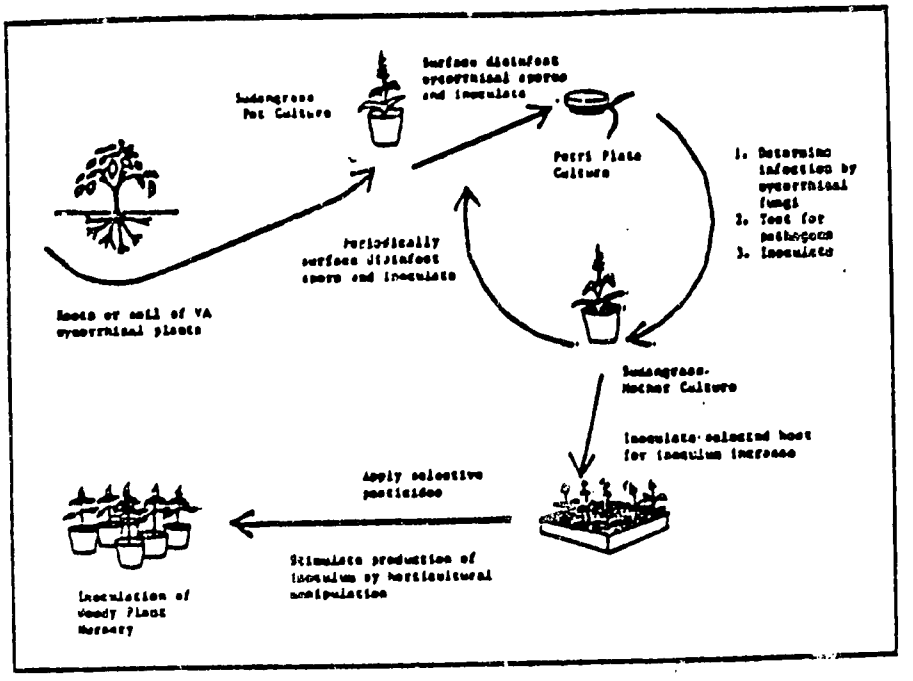

Fig. 1. Proposed scheme for commercial production of mycorrhizal inoculum.

Mycorrhizae may save fertilizer dollars

By Dr. Charles R. Johnson and Dr. John A. Menge

MYCORRHIZAL FUNGI are associated with the roots of nearly all plants. They form a symbiotic association termed mycorrhizae. Because of their importance to plant growth and their widespread distribution, mycorrhizae must be considered in all aspects of plant science and agriculture.

Mycorrhizal fungi are frequently categorized into four major groupings: ectomycorrhizae, vesicular-arbuscular (VA) mycorrhizae, ericaceous mycorrhizae and orchidaceous mycorrhizae. Ericaceous and orchidaceous mycorrhizae are associated with ericaceous and orchidaceous plants, respectively. Little information is available on these two types of mycorrhizae, and their economic importance is limited, so they

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Mycorrhizal inoculum costs

Item	Cost per pot
Cash Costs	
Management salary	7¢
Other wages & salaries	
Potting & inoculation	5
Moving pots	2
Pruning	1
Spraying	1
Watering (drip)	2
Harvesting	3
Grinding & packaging	2
Quality control	2
Maintenance mother culture	5
Plants & seeds	.2
Pots—4-inch	7
Media	2
Fertilizer	.3
Pesticides & other chemicals	1
Other production supplies	1
Repairs & maintenance	1
Insurance	2
Telephone	.5
Electricity & fuel	9
Taxes, licenses & bonds	1.1
Advertising	.3
Rent (land and/or buildings)	.8
Other cash expenses	15
Total Cash Costs	69.2¢
Noncash Costs	
Depreciation on machinery & equipment	2.2
Depreciation on buildings	.9
Interest on capital @ 12%	12
Total noncash costs	15.1¢
Total cost per 4-inch container	84.3¢

Fig. 2. Estimated costs for producing vesicular-arbuscular mycorrhizal inoculum on Sudan grass in four-inch pots.

Fertilizer cost comparison

Fertilizer: Material	Fertilizer: Rate[2]	Annual fertilization cost for 1,000 gallon containers[1]: Without VA mycorrhizae	With VA mycorrhizae	Potential savings
Micronutrients	2.5 lb/cubic yd	$22.14	$13.28	$ 8.86
Double superphosphate	5 lb/cubic yd	3.06	.91	2.15
Ammonium nitrate	Avg. 130 ppm N	37.81	26.47	11.34
Potassium chloride	Avg. 80 ppm K_2O	9.58	6.71	2.87
Other nutrients (Ca, Mg)		7.25	5.80	1.45
Totals		$79.84	$53.17	$26.67

[1]Based on January, 1981, price estimates.
[2]Fertilization rates based on commercial woody nursery operations using overhead fertigation system.
[3]Phosphorus levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA mycorrhizal fungi.

Fig. 3. Estimated fertilizer costs for woody landscape plants grown in gallon containers with and without VA mycorrhizae.

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will not be discussed further.

Ectomycorrhizae are associated with numerous conifers and other trees, such as oak, beech, birch, eucalyptus, willow and poplar. Ectomycorrhizal fungi are Basidiomycetes (mushrooms and puffballs) and Ascomycetes (cup fungi and truffles). They are characterized by a thick fungal layer, known as a fungal mantle, which covers the host feeder roots.

VA mycorrhizae are found on a majority of the angiosperms of the world. They do not visually alter the structure of roots and often cannot be detected without a microscope. VA mycorrhizal fungi are found in almost any field soil from arctic to tropical regions (17).

Both of these mycorrhizal types penetrate the outer regions of roots (cortical cells), but only VA mycorrhizae penetrate individual cells. Inside host plant cells, VA mycorrhizal fungi form branched structures known as arbuscules and ballon-like structures termed vesicles.

Arbuscules are thought to be the site of nutrient transfer between the symbiotic partners. Vesicles are likely storage organs that the fungus produces to store nutrient materials inside the plant host. Because a great majority of woody landscape species are infected by beneficial VA mycorrhizal fungi, this will be the only group of mycorrhizae discussed below.

What They Do

VA mycorrhizae are capable of improving growth of many woody landscape plants (10, 11, 12, 21). VA mycorrhizal fungi stimulate plant absorption of phosphorus and may be involved in uptake of other ions (4, 15, 16). Mycorrhizal fungi have been reported to improve water transport (19), although this may simply reflect improved nutritional status of mycorrhizal plants.

There is also evidence that mycorrhizae provide resistance to plant disease (20). Many scientists feel that VA mycorrhizal effects on disease are a result of improved phosphorus nutrition caused by the increased absorbing surface conferred by mycorrhizal hyphae.

Container production of ornamentals eliminates or significantly reduces populations of VA mycorrhizal fungi. Most media components—such as pine bark, vermiculite, perlite, builder's sand and peat mosses—are devoid of mycorrhizal fungi. In addition, many nurserymen steam, pasteurize or chemically treat media to eradicate harmful pathogens; this also eliminates beneficial organisms, such as mycorrhizal fungi.

Nurserymen have compensated for the absence of mycorrhizal fungi by applying luxury amounts of fertilizer and water to achieve desired growth. But high levels of nutrition and irrigation will not always be feasible, because of limited petroleum available for making inorganic fertilizer, high costs of fertilizer and rigid restrictions on water use. In addition, high nutrition and subsequent required pesticide applications are being more carefully monitored by environmental regulatory groups.

Inoculating container-grown plants with VA mycorrhizal fungi may reduce the need for current high levels of fertilizer, water and pesticides. This can be done, and it has some economic advantages.

Inoculum Production

Commercial production of VA mycorrhizal inoculum is being attempted at only a few places in the country. Currently, the only way to produce suitable quantities of inoculum is on roots of susceptible host plants. With the proper safeguards, mycorrhizal inoculum that is free of plant pathogens can be produced in commercial greenhouses.

Menge et al (13) proposed a scheme for producing inoculum as shown in Fig. 1. The inoculum is produced in pot cultures of selected hosts that have no root diseases in common with the host plant for which the inoculum is intended. For example, inoculum for citrus could be produced on Sudan grass but never on citrus.

Precautions must be taken to ensure the inoculum is free of nematodes, insects and harmful pathogens. Nemec (18) tested a number of fungicides that are compatible with producing mycorrhizal fungi.

Cost estimates of inoculum production can be generated using current greenhouse business analyses. A reasonably accurate cost estimate of mycorrhizal production, including technical labor and quality control, is approximately 84.3¢ for a four-inch container of VA mycorrhizal inoculum (Fig. 2). This would be enough to inoculate approximately 50 to 60 gallon containers.

A method similar to the one outlined above is being developed in England for large-scale commercial use (7). In this method, plants are grown in peat blocks that are standing in a shallow nutrient-flow culture. After VA mycorrhizal spores are produced in the peat blocks, the blocks are ground up for inoculation.

Inoculating Woody Landscape Plants

A number of methods have been used to inoculate plants with VA mycorrhizal fungi in greenhouse and nursery trials. Inoculation can be done when potting rooted cuttings into liner or gallon containers by placing five to eight grams of soil inoculum directly beneath roots of the cuttings. Phosphorus levels must be kept low (less than 34 parts per million for citrus) during all phases of plant growth, and other nutrients should be kept low for the first six to nine weeks of mycorrhizal infection.

Infection has also been accomplished by inoculating plants during propagation, shortly after root initiation, using mycorrhizal spores or soil inoculum. The greatest success with infection and subsequent growth response has been realized from early spring to summer.

Various methods have been used successfully to inoculate field-grown plants, including layering the inoculum under seed and banding the inoculum along plant rows (8). Commercial applications of mycorrhizal inoculum using fertilizer banding machinery were successfully carried out in a California citrus nursery (2). Some success has been achieved by pelleting seeds with inoculum (6) and by inoculating seeds (3).

Growth and Economic Benefits

Because VA mycorrhizal fungi occur on a wide variety of woody plant species and improve growth of these plants, the potential of these fungi as commercial "biotic fertilizers" is enormous.

Researchers have shown that woody landscape plants in containers grow about as well with low to moderate nitrogen and potassium fertilization plus mycorrhizal inoculation as they do with luxury fertilization (10).

Benefits of these fungi on important tree fruits, such as citrus (13), avocado (14) and peaches (11), has prompted inquiries and demand for inoculum to improve plant growth.

Fertilization currently constitutes two to four percent of the cash nursery production expenses (5). This will continue to rapidly escalate.

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With inoculation, the expense of phosphorus fertilization could be reduced by approximately 70 percent. Current levels of nitrogen, potassium and micronutrients could be reduced by 30 to 40 percent.

This potentially could reduce fertilizer expenditures by 33.4 percent, for savings of approximately $26.67 per 1,000 gallon containers annually for woody plants under a typical fertilization program (Fig. 3).

Preliminary research has indicated that an additional benefit is improved establishment and survival of mycorrhizal plants in landscape soils (9). Reduced costs for better water and fertilizer uptake and improved plant survival should create consumer demand for such plants in the landscape.

Summary and Conclusions

Mycorrhizal fungi benefit growth of several woody landscape plants under controlled experimental conditions. Cost benefit figures indicate an economic advantage to using them. Container studies are being established at nursery sites to test the feasibility of using mycorrhizal fungi under commercial culture programs.

With successful results from such tests and growing interest, more commercial sources of inoculum should develop. Current methods of watering and fertilizing will be radically changed in the next decade because of shortages. Using alternatives like VA mycorrhizae will become common.

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SECTION IX

Hamilton, J.L. and R.H. Lowe. 1982. Use of a Water Absorbent Polymer in Tobacco Seedling Production and Transplanting. Tobacco Science, XXVI: pp. 17-20.

USE OF A WATER ABSORBENT POLYMER IN TOBACCO SEEDLING PRODUCTION AND TRANSPLANTING[1]

By JAMES L. HAMILTON and R.H. LOWE[2]

The use of a water absorbent polymer (WAP) to aid in the production of burley tobacco transplants and to increase the survival of transplants was investigated. WAP held water in contact with the seed, and improved the rate and uniformity of germination in a leached soil. This effect of WAP was destroyed by fertilizer salts. A slurry of WAP and water as a root dip maintained roots in a moist condition, reduced wilting of the seedlings, and resulted in better survival, less resetting, earlier growth, and more uniform early growth compared to nontreated seedlings.

INTRODUCTION

One of the major causes of poor stands in tobacco plant beds is drying of the soil surface soon after the seeds germinate. Tobacco seed are generally sown without cover on the surface of the soil. If environmental conditions cause the soil surface to dry before the root penetrates the soil, the seedling may die even if there is adequate moisture below the soil surface. "Super slurper" (ss), a water absorbent polymer (WAP) (1), can absorb 2,000 times its weight of distilled water. Although lesser amounts of water are absorbed if salts are present, WAP may have potential for improving seed germination in plant beds and for maintaining turgidity of transplants. Application of WAP to a plant bed may reduce watering requirements and minimize drying of the soil surface. Proper management requires frequent watering to prevent such drying, so the use of a WAP could reduce labor requirements.

Seedlings pulled for transplanting often are held for hours or days before transplanting. Desiccation of roots may reduce seedlings survival, particularly during hot, dry seasons. Recovery of plants after transplanting will be delayed until new roots are initiated from the tap root or stem. Treatment of the roots of transplants with a WAP may reduce such desiccation.

The present report provides information on a specific WAP (1) relative to germination of tobacco seeds in mixtures with soil, the capacity of such mixtures to retain water, the effects of salts on water retention, and protection of transplants from desiccation prior to transplanting.

MATERIALS AND METHODS

Soil treatment at seeding: An area in a greenhouse soil bed 120 cm wide and 210 cm long was divided into 28 squares, 30 cm to the side, making 4 series of 7 plots long. A WAP[3] was randomly applied at rates of 0, 0.5, 1.0, 2.0, 5.0, 10 and 20 g per 900 cm^2, to each series. These rates are approximately equivalent to 1, 2, 4, 10, 20 and 40 lbs per 9 ft by 100 ft tobacco bed. Approximately 90 seed per 900 cm^2 were broadcast on each square.

Method of WAP application differed with each series. In series 1, the seeds and WAP were broadcast on the soil surface. In series 2, the seeds, WAP, and 25 g of soil were mixed, then broadcast on the soil surface. In series 3, the seeds, WAP, and 500 g of soil were mixed, then broadcast on the soil surface. Finally in series 4, the seeds, WAP, and 50 g of sand were mixed, then poured in rows, 6 cm between rows, across the plot.

[1]Contribution of the Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, and the Agricultural Experiment Station, University of Kentucky. Publication Number 80-3-108.

[2]Plant Physiologists, SEA, USDA, AR, Agronomy Department, University of Kentucky, Lexington, Kentucky 40546.

Contribution received Sept. 9, 1980. Tob. Sci. XXVI: 17-20, 1982.

[3]Super slurper from Large Blender Run No. 8, provided by Dr. George F. Fanta, Cereal Products Laboratory, Northern Regional Research Center, Peoria, Illinois.

After the combined seeding and treatment operation, the plots were watered, then covered with tobacco canvas. No additional water was applied for 7 days. Plant stands were determined 11 days after seeding.

Effects of soil, fertilizer and salts on water retention of WAP: Weight of distilled water retained by 0.2 g of WAP alone or combined with 20 g soil, 20 g leached soil, 20 g leached soil plus 1 g of 6-12-8 fertilizer, 1 g $Ca(NO_3)_2$, 1 g $Ca(H_2PO_4)_2$, 1 g KNO_3 or 1 g of KH_2PO_4 was obtained to determine effect of mixture on water retention. The amount of water retained by each mixture was measured by weighing. The water held by the soil was determined and the grams of water held by one gram of WAP calculated. Soil used in this test was a Maury silt loam.

Plant treatment at transplanting: In the first year of tests, roots of burley tobacco, cultivar Ky 14, and of flue-cured, cultivar NC 95, were dipped into a gel containing 4 g of WAP per liter of distilled water at the time of pulling. Excess material was shaken off and the plants placed in a container to take to the field. Nontreated plants were pulled and kept the same way. The plants were transplanted about 4 hrs after pulling with a commercial tobacco transplanter into 3-row plots, each 35 m long, in triplicate. Approximately 200 ml of water was applied with each plant at transplanting.

In the second year of tests, only burley tobacco, cultivar Ky 14, was used since no difference between tobacco classes was observed in the first year. Plants were pulled and dipped into a gel of WAP, the same as the first year, then wrapped in burlap and stored in a barn until transplanted. Nontreated plants were pulled and kept the same way. Plants were transplanted 1, 6, and 24 hr after pulling with a commercial tobacco transplanter into 2-row plots, each 30 m long, in triplicate. Approximately 200 ml of water was applied with each plant at transplanting in one of the rows. No water was used at transplanting in the other row. The number of dead and severely wilted plants were counted one week after transplanting.

RESULTS AND DISCUSSION

Soil treatment at seeding: WAP treatments of 1-2g per 900 cm^2 (2-4 lbs per 100 sq. yd. bed) increased the percent germination of tobacco seeds for each method of application (**Table 1**). However, the 1 g rate was as effective as the 2 g rate when soil was mixed with the seed and WAP. The percent germination decreased at higher rates. When used alone, WAP made a gel on the surface that would stick to the plant bed cover if touched. Germination was poor with the 20 g per 900 cm^2 treatment, undoubtedly because the gel exceeded 2 cm thick at the time of the initial watering. Mixing the seed, WAP, and soil made it easier to get the seed and WAP uniformly distributed over the bed. When more than 2 g of WAP was mixed with 25 g of soil, the mixture would form a crust that destroyed many young seedlings. Application of a seed, WAP, and sand mixture in rows was unsatisfactory as WAP combined with the sand to form an impenetrable medium for germinating seeds. Accordingly, data for these treatments were omitted.

Subsequent field tests failed to show improved germination with WAP compared to check treatments. Some laboratory studies were conducted to find out why. Soil from near the area of the plant beds would only retain 110 g of water per gram of WAP, whereas, the same soil when leached retained 600 g of water (**Table 2**). It appeared that the success in the greenhouse soil floor beds was due to our method of watering (flooding the soil), which had leached the soil surface. When 1 g of a 6-12-8 fertilizer was added to the leached field soil, water retention was reduced to below the level of the original field soil sample. Calcium or potassium salts decreased the water-holding capacity of WAP (**Table 2**). The divalent calcium ion decreased the water-holding capacity more than the monovalent potassium ion. Anions did not seem to affect water retention of WAP. The hydrophilic polymer of WAP is an anionic starch derivative that absorbs and retains the dipolar water molecule. The affinity of WAP for the cations calcium and potassium was greater than it was for water; thus, the cations destroy the usefulness of WAP.

Table 1. Effects of a water absorbent polymer (WAP) and method of application on percent germination.

WAP g/100 cm^2	Methods of Application: WAP on surface	WAP + 25 g soil	WAP + 500 g soil	Avg
0	34	41	36	37
0.5	71	24*	86	78*
1	79	96	98	91
2	92	97	100	96
5	72	80	94	82
10	34	33	88	52
20	19	20	39	26

*Damaged corner plot; not included in avg.

L.S.D. (0.05) of the mean = 11.6

Table 2. Effect of soil, fertilizer and salts on waterholding capacity OF WAP.

Basic treatment	Added component	Water retention g/g WAP
200 ml water plus 0.2 g WAP	0 g Soil	925
	20 g Soil	110
	20 g Leached Soil	600
	20 g Leached Soil + 1 g Fertilizer (6-12-8)	75
	1 g $Ca(NO_3)_2$	15
	1 g $Ca(H_2PO_4)_2$-H_2O	20
	1 g KNO_3	95
	1 g KH_2PO_4	100

Development of a mechanized transplanting operation is inhibited by lack of uniformity in seedling spacing and growth (3). WAP could be useful for such development as adhesive properties would keep spaced seeds in place and water retention characteristics would assure adequate moisture for germination. However, WAP would be useful in such application only if the soil was initially leached and if fertilization was accomplished after germination.

Plant treatment during transplanting: The first year of the test 95% of the plants dipped into a WAP gel survived, while only 65% of the nondipped plants survived. There were no differences between the two classes of tobacco. After 3 days, only the bud and stalk remained of the nontreated plants which did survive, while the WAP-treated plants retained most of their plant bed leaves (**Fig. 1**). At this time only the main tap root of surviving check plants was alive. Fibrous roots of treated plants were in good condition. After the check plants had started to grow (about 2 weeks after transplanting), both the treated and nontreated plants were dug up and the roots washed free of soil and examined. At this time WAP-treated plants were larger and had a larger and more extensive root system than untreated plants (**Fig. 2**).

Hot and dry weather at the time of field transplanting during the first year caused poor survival of nontreated plants. Many farmers in the area who transplanted during this period had sim-

Fig. 1. Appearance of tobacco seedlings during hot and dry conditions three days after transplanting. Roots treated with WAP on right, no treatment on left.

ilar survival rates and several fields were disked and reset. Apparently the WAP enhanced survival by preventing root desiccation so that after transplanting they continued to grow. The fibrous roots on the check plants became desiccated and died. New roots are initiated on the tap root and stem, and in dry, hot weather some of the plants died before the new roots developed.

Transplanting conditions were ideal in the second year of the testing and each treatment was transplanted with and without water in order to create stress. The second column of Table 3, water and no WAP, represents the conventional burley tobacco transplanting practice. With seedlings transplanted one hour after pulling, there was no difference in survival between treated and untreated plants. With seedlings transplanted 6 hr after pulling survival improved with treatment, either with or without water. The WAP-treated plants held 24 hours after pulling had not wilted at the time of transplanting, while the untreated plants varied from slightly wilted to severely wilted. We biased the experiment by discarding the severely wilted plants from those held 24 hr before transplanting, as the farmer would have done. The discarded plants probably would not have lived. This culled the weak plants from the plant bed and probably accounts for the high survival rate of the check plants set 24 hr after pulling compared to those set 6 hr after pulling. Dipping the roots of plants into a slurry of water and WAP at the time of pulling decreased considerably the amount of resetting necessary in a poor season but not in a good season.

The number of severely wilted plants one week after transplanting was reduced considerably by WAP treatment at all transplanting times. Replacement of dead plants with newly-pulled seedlings was made one week after transplanting. One week later the new resets were bigger and growing better than the plants that were severely wilted at the time of resetting. Considering the number of dead and severely wilted plants one week

Fig. 2. Appearance of tobacco seedlings two weeks after transplanting. Roots treated with WAP on right, no treatment on left.

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Table 3. The effects of WAP and water on tobacco transplant survival one week after transplanting.

Time[1/]	With water		Without water	
	No WAP	With WAP	No WAP	With WAP
	Percent survival			
1 hr	98	98	94	98
6 hr	86	93	69	89
24 hr	90*	89	67*	70
	Percent severely wilted			
1 hr	2	0	11	4
6 hr	16	8	27	21
24 hr	20*	12	53*	40
	Percent dead and severely wilted			
1 hr	4	2	17	7
6 hr	30	14	58	32
24 hr	30*	23	87*	70

[1/] Time between end of pulling and start of transplanting.

*Severely wilted plants were discarded before transplanting.

after transplanting, there was a big advantage for using WAP when transplanting was delayed more than 1 hr after pulling.

Dipping plant roots into a WAP gel at the time of pulling protects the roots from drying. These roots appear to continue to function and grow, thus they are able to get more water from the soil which reduces the amount of wilting and increases the number of plants that survive. DeRoo (4) studied the survival of tobacco transplants treated with decenylsuccinic acid and its monoglyceryl ester. These compounds have been shown to reduce transpiration. Survival was not increased by treating with these compounds. Collins *et al* (2) reported a slightly higher yield of flue-cured tobacco in a dry season when transplants were treated with an anti-transpirant. Protecting the roots with WAP resulted in less resetting and more uniform early growth of tobacco plants. It appears that the use of WAP would reduce the labor of resetting and more uniform growth would require fewer trips over the field for topping and applying sucker control chemicals. Also, good growth and plant uniformity early in the season are generally associated with higher yields.

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1. Anonymous. Super slurper, compound with a super thirst. Agricultural Research, June 1975.
2. Collins, W. K., S. N. Hawks, Jr. and B. U. Kittrell. Yield response of flue-cured tobacco to an anti-transpirant applied to transplants. Tob. Sci. 13:70.
3. Cundiff, J. S. Precision seeding of tobacco plant beds. Tob. Sci. 21:5-6. 1977.
4. DeRoo, H. C. Survival of tobacco seedlings, as affected by decenylsuccinic acid and transplant size. Tob. Sci. 10:154-156. 1966.

SECTION X

Gibson, P.G. and C.E. Whitcomb. undated. Substitutinng Starch Based Absorbents for Peat. Oklahoma University.

Substituting Starch Based Absorbents For Peat

Philip G. Gibson and Carl E. Whitcomb [1]

Objectives: To determine 1) if peat can be replaced in a soil mix by TERRA-SORB 200 or 201 without restricting plant growth and 2) if elemental sulfur influences its performance.

Peat moss is probably the most expensive ingredient in most soil mixes. It provides aeration, some nutrients and most importantly, water retention to the media. If peat could be partially or totally replaced by another less expensive additive without sacrificing the properties of the original mix, a more economical growing medium could be developed. This would save the nurseryman money and maybe save water. Also, a better quality crop may be the net result. Therefore, the use of TERRA-SORB 200 and TERRA-SORB 201 as a soil additive, instead of peat, seems appropriate to investigate.

Super absorbent is the generic name for starch-based absorbents. TERRA-SORB is made by grafting man-made acrylic compounds to cereal grain starch and hydrolizing the combination. These compounds can absorb 200 to 5,300 times their own weight in water. For example, one pound of TERRA-SORB 200 will absorb 20 to 25 gallons of water or about 50 times as much moisture as peat. The absorbents maintain their water-holding ability for 6 months to a year or more. The material expands to as much as 30 times its original size thus the expansion could provide increased soil aeration.

The addition of these absorbents to a container growing medium could shorten transplant recovery, quicken root system development and turn inventories faster. Thus, the need for research on levels of absorbent and relative media systems.

Methods: Treatments were 0, 1, 2, 4 pounds/cu. yd. of TERRA-SORB 200 or TERRA-SORB 201 added to a growing medium of 3 parts bark and 1 part sand. A growing medium of 3 parts bark, 1 part peat and 1 part sand was used as a control. Sulfur was added to half of each of the treatments at a rate of 6 pounds/cu. yd. to test its effect on biodegradation of the starches.

All growing media received a standard rate of 14 pounds/cu. yd. of osmocote 18-5-11, 1.5 pounds/cu. yd. of Micromax, 1.5 pounds/cu. yd. of super phosphate, 8 pounds/cu. yd. of dolomite and 2 pounds/cu. yd. of gypsum. No liquid fertilizer was used.

On May 9, 1980, 108 rooted Juniper *Juniperus procumbens* cuttings were planted in one gallon white poly bags. Each replication consisting of cuttings approximately the same size and vigor. On June 12, 1980, 108 lacebark elm (*Ulmus parvifolia*) seedlings were planted in two gallon white poly bags. Each replication consisting of seedlings approximately the same size and vigor. All plants were randomized and placed on a black poly covered bed according to replications. They were immediately watered in with overhead sprinklers following planting. They received full sun and daily overhead watering as needed.

1. Oklahoma University, Stillwater, Oklahoma

On October 28, 1980, the lacebark elm trees were evaluated by height and stem caliper. On October 30, 1980, the junipers were evaluated by top and root weight and the number of branches developed.

Results: The sulfur treatment proved to be consistently and significantly detrimental in all cases and is therefore omitted from the evaluation.

Lacebark elm seedlings grew as well in the mixture with 3 parts bark, 1 part sand and all rates of TERRA-SORB 200 or 201/cu. yd. as did the bark-peat-sand control (Table 1). The elm trees were able to utilize the water held even at the 4 lb. rate of either TERRA-SORB product.

The junipers grew as well in the TERRA-SORB 200 and 201 at the 2 lbs./cu. yd. rate as the bark-peat-sand control (Table 1). However, the 4 lbs./cu. yd. rate of either product was too wet for the junipers and some showed root growth restriction. The 2 lb. rate, especially of TERRA-SORB 200, gave good, lush top growth, as well as good, healthy root growth. The use of an absorbent in a soil mix appears to have potential. Its performance on a wider variety of species and with a variety of fertilizers should be studied.

Table 1. Plant growth response to TERRA-SORB 200 and 201 incorporated into the growing medium as a substitute for peat.

Species	Measurement	Bark-Peat-Sand Control	Bark-Sand Control	TERRA-SORB 200 lbs./cu.yd. 1	2	4	TERRA-SORB 201 lbs./cu.yd. 1	2	4
Elm	height (cm)	73_b	71_b	73_b	72_b	71_b	70_b	76_b	72_b
	stem caliper (cm)	$.94_a$	84_a	$.89_a$	$.88_a$	$.97_a$	$.85_a$	$.89_a$	$.96_a$
Juniper	root weight (g)	47_{ab}	47_{ab}	40_{ab}	[illegible]$_b$	38_a	35_a	44_{ab}	34_a
	top weight (g)	35_b	30_a	34_{ab}	36_b	31_{ab}	29_a	34_{ab}	28_a
	# branches/plant	6_b	5_a	5_a	6_b	5_a	6_b	6_b	5_a

SECTION XI

Virginia Tech Field Days Report. Sept. 15-16, 1981. The Benefits of Using TERRA-SORB for Sodding Applications. pp. 60-67.

THE BENEFITS OF USING TERRA-SORB FOR SODDING APPLICATIONS

ABSTRACT

In the test series TERRA-SORB 200 and several experimental forms of TERRA-SORB (TERRA-SORB 201,350,1000) were tested. TERRA-SORB was also tested in combination with other chemicals or other sod treatments.

For sod grown under natural conditions with supplemental irrigation TERRA-SORB increased the percentage of green cover and increased root strength. Where the aerified sod was soaked in a slurry consisting of 19 grams of TERRA-SORB per gallon of water root strength was 3.6 kilograms per 900 square centimeters. The root strength of the control was 2.3 kilograms per 900 square centimeters. The application of TERRA-SORB resulted in an increase in root strength of 56 per cent.

Where sod was washed free of soil and soaked in a slurry consisting of 12 grams of TERRA-SORB 350 per gallon of water the root strength increased from 1.4 grams per 900 square centimeters (control) to 4.8 grams per 900 square centimeters (TERRA-SORB 350). An increase of 242 per cent.

In the test the percentage of green cover generally increased with the application of TERRA-SORB. The maximum increase was noted for sod that was washed free of soil and treated by dipping in a slurry consisting of 12 grams of TERRA-SORB 350 per gallon of water. Green cover percentage for the control (washed free of soil) was 53.3%; the TERRA-SORB treated sod had a green cover percentage of 90.7, an increase of 37%.

The tests also tend to indicate that a wetting agent (Aqua-Gro) can be beneficially applied with TERRA-SORB by providing better water penetration. Root strength increased from 2.8 kilograms per 900 square centimeters to 3.6 kilograms per 900 square centimeters when Aqua-Gro was applied with TERRA-SORB. When Aqua-Gro or TERRA-SORB was used alone root strength was measured at 2.8 kilograms per 900 square centimeters.

Future studies are planned to study the combination of the most promising treatments.

Reported in the Virginia Tech Field Days Report, Sept. 15 & 16, 1981, Virginia Polytechnic Institute.

SECTION XII

U.S. Army Corps of Engineers. undated. Specifications for Deciduous Trees and Shrubs. Solicitation No. DACW62-82-B-0074.

PART I - THE SCHEDULE

SECTION C - DESCRIPTION/SPECIFICATIONS

SPECIFICATIONS FOR
DECIDUOUS
TREES AND SHRUBS

1. General. All trees and shrubs specified herein shall be first quality nursery stock grown from seed. All seedlings shall be bare-root, dormant seedlings alive and in a healthy growing condition, free of disease, insects, insect eggs and larvae. Root systems shall be adequate, live damp, fibrous, and free of rot and mold.

2. Digging and Handling. Precautions shall be made during digging and handling operations to insure that roots do not dry out. Seedlings shall be placed in cold storage within 24 hours after digging.

3. Pruning. When pruning of seedlings is necessary to meet the size requirements, the following shall apply.

a. Roots and trunks ¼" in diameter and greater may not be pruned.

b. The maximum length that may be pruned from roots is 4".

c. The maximum length that may be pruned from trunks is 8".

4. Substitutions. Consideration will be given to bids containing substitutions. Substitute species shall meet the same size requirements as those species they are intended to replace. The Government reserves the right to refuse bids in whole or part that have substituted seedling species.

5. Standards. All seedlings shall comply with applicable State and Federal requirements. All necessary quarantine or other certificates shall accompany the shipment of seedlings.

6. Size Requirements. Measurements of length of trunks and roots shall be made from the root collar. Sizes for seedlings shall be as follows:

Roots - Length 4"-7"
Caliper ½" maximum at root collar

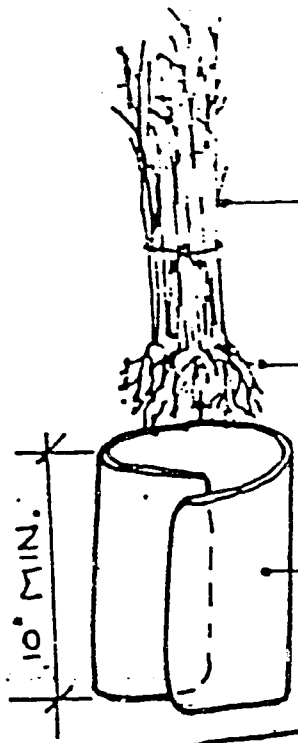
Trunks - Length 8"-16"
Caliper 1/8"-½"

7. Packaging. Seedlings shall be bundled and tied in groups of 500 or less and doubled bagged in "Kraft", or equal, poly lined paper bags. Seedling roots shall be treated with "Terra - Sorb", or equal, moisture retaining root conditioner and wrapped with "Root Wrap", or equal, non-organic non-woven moisture retaining fabric blanket. The fabric blanket in each package shall

be sufficiently moist. Each package shall be labeled to show the quantity, botanical name, common name, and name of the supplier. Each package shall not exceed 50 pounds in weight. Packaging shall be in accordance with EXHIBIT A, Page C-3.

8. Shipping. Seedlings shall be delivered on date required by the Government, 29 November 1982. Seedlings shall be delivered within 48 hours from the time that they are shipped from the nursery, or shipped by UPS. Seedlings shall be reloaded at the delivery site into a Government provided storage unit by the shipper.

9. Rejection of Seedlings. Plants damaged in transit or not conforming to the specifications will be rejected within a three-week period. The supplying nursery will be notified by telephone and given 48 hours to inspect the seedlings. After 48 hours have expired, the Government may dispose of rejected plants and will not be liable for their payment.



8"-16" SEEDLINGS, BUNDLED IN GROUPS OF 500 OR LESS

ROOTS, TREATED WITH "TERRA SORB" OR APPROVED EQUIVALENT ROOT CONDITIONER

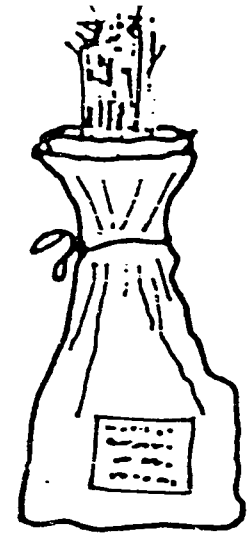
POLY FILM OR MOISTENED FABRIC BLANKET SUCH AS "ROOT WRAP". LOOSE MULCH SUCH AS PEAT MOSS, WOOD SHAVINGS, MOSS, OR PAPER MULCH ARE NOT ACCEPTABLE

2 "KRAFT" TYPE POLY LINED PAPER BAGS

CORD

LABEL

EXPLODED VIEW OF SEEDLING PACKAGE



COMPLETED SEEDLING PACKAGE

NOTES:

1. SEE SPECIFICATIONS FOR ADDITIONAL DETAILS
2. BIDDERS ARE REQUIRED TO SUBMIT (with bid) THE BRAND NAM MANUFACTURER, AND IDENTIFICATI NO. FOR THE FOLLOWING:
   - FABRIC BLANKET or POLY FIL
   - ROOT CONDITIONER
   - POLY LINED BAGS

(Samples may be submitted in lie