AN EVALUATION OF BRACKISH WATER FOR GROWING NURSERY CROPS UNDER HYDROPONIC CONDITIONS

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ABSTRACT

The growth of afghan pine (Pinus eldarica), pistachio (Pistasia atlantica) asparagus (Asparagus officinales), iceplant (Lamprathus spectablis), portulaca (Portulaca grandifolia) and statice (Limonium sinuatum) was evaluated under different levels of brackish water using various methods of hydroponic culture. Rates of brackish water tested included a full strength (1X) brackish water solution made by copying the analysis of a water from Roswell, New Mexico. This water had an electrical conductivity (EC) of 24 mmohs/cm, and over 14,000 ppm total dissolved solids. The predominant ions were chloride, sodium and calcium. Dilution of the water were as follows, 0.75X, 0.50X, 0.25X, 0.125X and 0.06X. Hoagland's complete nutrient solution (HCNS) was added to all test solutions and when used alone was the control treatment. In solid media tests all species, except pistachio, survived and grew under the highest concentration of brackish water. However, growth rate declined abruptly when brackish water levels exceeded 0.125X (iceplant, statice) 0.25X (pistachio, portulaca), or 0.50X (afghan pine, asparagus). The results are encouraging with the solid media and more work appears warranted. In the liquid media tests (nutrient film technique and aerated nutrient solution) plant growth was sporatic and generally non thrifty in all brackish water plots. This was true even after seedling had been established in water or Hoagland's solution and evidence of many healthy new roots was present. There were colonies of fungi and bacteria on the roots, but it was not determined whether these microorganism were pathogens causing the plant decline or whether they were opportunistic saprophytes responding to saline

water induced root damage. It was concluded that the liquid methods offer little promise for nursery plant production.
Key words: Salinity, brackish water, ground water, greenhouse production, hydroponic culture, soilless culture, afghan pine, pistachio, iceplant, asparagus, portulaca, statice.

INTRODUCTION

The availability of suitable quality water for production of irrigated mesophytic plants in New Mexico is limited. The total ground water in New Mexico is approximate 20 billion acre feet, of which 15 billion acre-feet are brackish. These ample reservoirs of substandard water may have potential for use in plant agriculture in New Mexico. Although specific characteristics of such waters vary, all are too saline to be used for traditional irrigated agriculture. However, the salinity is often low enough that it may be of use in growing some crops under specialized circumstances. "Brackish Water in Hydroponic Culture of Two High-Value Nursery Crops, Pistachio and Afghan Pine" was a one year WRRI funded project conducted by the authors in the Department of Horticulture, New Mexico State University. Work began in June 1984 and continued through July 1985. This report describes research conducted to evaluate the usefulness of brackish water for the production of high-value nursery crops grown under intensive greenhouse management regimes.

REVIEW OF LITERATURE

Hydroponics, a system of providing the essential plant growth mineral nutrients in water, was originally designed and used by scientists in their study of growth and mineral element requirements of plants (Steiner 1985), and later it was commercialized for food production (Hoagland and Arnon 1938). Originally its commercial use was restricted to environments where water or arable land limited production by traditional methods. More recently expanded worldwide interest led to a conference entitled "Hydroponics Culture; Worldwide - State of the Art in Soilless Crop Production." The conference was held in Honolulu, Hawaii, in February 1985. This conference clearly marks a resurgence of interest in commercial applications of hydroponics.

Root anchorage and plant support must be supplied in solution hydroponics systems. With soilless solid media systems (often referred to as hydroponics culture also), nonsoil materials support the plant in a manner similar to that of soil. Media such as sand, peat gravel, scoria, and mixtures of vermiculite, bark, sawdust, peat, and perlite, have been used successfully (Cotter and Corgan 1974; Johnson 1985). A complete plant nutrient solution is regularly added to these media. Medium solution retention may be limited (particularly with the course aggregate materials), and this requires frequent rewetting throughout the day. Conventional greenhouse and nursery systems usually deliver nutrient solutions in appropriate quantities and times so that the medium is fully wetted and a small amount leaches away (about 10 percent). In hydroponic culture the nutrient solution can be recycled or used only once. Recycling requires a storage tank of substantial size and a nutrient monitoring system. Frequently one-time use of a solution is convenient.

Even more recently, techniques that deliver complete nutrient solutions to the roots in a continuous nutrient film, (Cooper 1979, 1985; Edwards 1985) or as an aerial spray within a rooting chamber (Stoffer 1985) have been described and used successfully. Both systems recycle the nutrient solution and require special plant supports.

Regardless of the system, the availability of adequate oxygen (O_2) in a root zone is essential. Many ways have been adopted to provide aeration. Air can be bubbled through the solution, the solution may be agitated to increase the air-solution interface or the solution can be sprayed over the roots growing in air. The use of a porous open organic medium such as peat also provides excellent aeration. All approaches to aerating roots have advantages and limitations, but each has been used successfully.

A more recent nutrient film technique (NFT) innovation reported by Cooper (1985), is the use of a split root technique that alternately provides dissolved nutrients to one half of the root system at a time. In the other half, root O_2 exchange is enhanced.

Research is extensive on the effects of salinity on economic field and horticultural crops. Plant physiological responses to salinity (Shannon 1979; Flowers 1977; Greenway and Munns 1980), and genetic screening of mesophytes to select genotypes that grow under saline conditions (Parson 1979; Rush and Epstein 1981) have received considerable attention. However, comparatively little has been done to evaluate intensively managed high-value nursery crops growing in brackish water.

Compared to most fruit and nursery perennials, improved cultivars of pistachio, Pistacia vera L., are noted to be relatively salt tolerant. Limited growth has occurred when soil EC exceeded 22 mmhos/cm (Parsa and Karimian 1975). Spiegel-Roy et al. (1977) reported that the growth and yield of pistachio under natural drought and salinity stresses varied in accordance to natural rainfall in the Negev Desert highlands, but exceeded that of all other fruit crops under run-off farming. Under containerized conditions growth of two pistachio cultivars was good when irrigation water of up to 4.5 mmhos/cm was applied to soil with resulting EC of 13 to 15 mmhos/cm (Sepaskhah and Maftoun 1981). The cultivar Fandoghi was more resistant than Badami. In most cases improved P. vera cultivars are budded on P. atlantica root stock.

Afghan pine (Pinus eldarica) is rapidly changing domestic landscapes of southern New Mexico, Arizona and West Texas. Due to its multiple-use potential, this pine is being grown in rapidly increasing numbers in southwestern nurseries and plantations (Fisher and Widmoyer 1978). This species is unusual among pines because it grows rapidly on alkaline soils. It has been successfully cultured in southern New Mexico plantations receiving water considered to be of moderate quality. However, no information is available on its ability to survive and grow under saline conditions. However, Pinus halepensis was not seriously affected when grown in a soil receiving irrigation water having an EC of above 11 mmhos/cm (Francois and Clark 1978). Due to its close taxonomic proximity to P. halepensis, one would predict that the afghan pine possesses salt tolerance.

Other nursery crops that hold promise for culture under brackish water include Japanese pagoda tree (Sophora japonica) and honey locust (Gleditsia triacanthos). Both grew reasonably well during a five week exposure to 7,000 ppm NaCl under hydroponic conditions (Townsend 1980). Francois and Clark (1978) evaluated salt tolerance of ten shrubs and found two tree and four iceplant species which were salinized with NaCl and CaCl. Six species, including four species of iceplant (Hymenocyclus croceus, Lamprathus productus, Drosanthemum hispidum, and Delosperma alba), Texas sage (Leucophyllum frutescens) and brush cherry (Syuzygium paniculatum) were unaffected by 7 mmhos/cm soil EC. The estimated salinity at which 50 percent of the plant population died was above 13 mmhos/cm.

PROCEDURES

Three approaches were employed to evaluate the usefulness of hydroponic systems in nursery crop in production.

1. Aerated Solution: The traditional form where plant roots grow in an aerated complete nutrient solution. Aeration was achieved by vigorously bubbling air through the solution with air pumps and airstones.
2. NFT: A modification of the aerated solution system where a nutrient solution is pumped from a reservoir tank to the top of inclined troughs in which plant roots were growing. The solution slowly flows down the incline and returns to the tank for recycling. Aeration is achieved by the agitation of the solution while returning to the resevoir.
3. Soilless Culture: This version consisted of a system where solutions were applied to plants growing in peat-vermiculite or fine silica sand media. The solutions were applied excess quantities so that a portion of the liquid leaches away.

Solutions Evaluated

The basic brackish water used in all tests was one that mimicked brackish ground water from Roswell, New Mexico (appendix 1 for full analysis). The water contained more than 14,000 ppm total dissolved solids, had an EC of more than 22 mmohs/cm with the following predominating ions: chloride (7179 ppm), sodium (4600 ppm), sulfate (1532 ppm) and calcium (534 ppm).

The components used to create the brackish synthate are listed in table 1. The EC of the synthate was approximately 24 mmhos/cm. It was synthesized in lots of 100 to 125 liters at a time. This full strength

Table 1. The formula for synthesizing brackish water typical of the Roswell, New Mexico brackish water source and the Hoagland complete nutrient solution (Hoagland and Arnon 1950).

Brackish Water

CHEMICAL	Mg/Liter
KCl	4.20
$CaCl \times 2H_2O$	1,196.20
$MgCl \times 6H_2O$	1,145.50
$NaSO_4$	2,081.71

HOAGLAND COMPLETE NUTRIENT SOLUTION FORMULA

Stock solution	Final Dilution (ml/l)
1 M $NH_4H_2PO_4$	1.0
1 M KNO_3	6.0
1 M $Ca(NO_3)_2 \times 4H_2O$	4.0
1 M $MgSO_4 \times 7H_2O$	2.0

Micronutrient stock solution	g/l
H_3BO_3	2.86
$MnCl_2 \cdot 4H_2O$	1.81
$ZnSO_4 \cdot 7H_2O$	0.22
$CuSO_4 \cdot 5H_2O$	0.08
$H_2MoO_4 \cdot H_2O$	0.02

Use 1 ml/l of complete nutrient soln.

Iron: 0.5% chelated iron solution
Use 2 ml/l of nutrient soln.

synthate (1.0X) was then diluted with tap water to produce 6.25 percent, 12.5 percent, 25 percent, 50 percent and 75 percent brackish water (used in the gradient and aerated solution studies) or 20 percent, 40 percent, and 60 percent (used in NFT) of its original strength (now referred to as 0.06X, 0.125X, 0.25X, 0.5X and 0.75X or 0.2X, 0.4X, and 0.6X respectively). To each of these treatments a full strength (HCNS) was added (table 1). Solution pH was adjusted to 6.0 with 0.5N HCl to assure peak phosphorus and micronutrient availability.

Plant Materials

The afghan pine seedlings used in these tests were obtained from the Silvicultural Research Unit, Department of Horticulture, New Mexico State University. Seedlings (60-90 days old from sowing) were grown under optimum greenhouse "long day" conditions and fertilized regularly with HCNS. They were grown in 150 cubic cm white plastic Ray Leach ('RL') tubes that were 20 cm long and tapered from a top diameter of 4 cm to a blunt pointed, perforated bottom. Tubes were filled with a 2:1 (v/v) peat vermiculite mixture or fine silica sand media. Usually seedlings of the same chronological age were selected for uniformity of size and vigor within a complete block. In the NFT test, the seedlings were selected based on phenotypic vigor in the same age group rather than on uniformity. Average initial height and caliper were 7-15 cm and 20 mm respectively.

Seeds and seedlings of P. atlantica (root stock) were obtained from Agri Development Co. of Orienda, California. Treated seeds were sown into RL tubes containing a 2:1 (v/v) peat: vermiculite or fine silica sand media and treated similarly to the afghan pine seedlings. When the experiment began, the pistachio seedlings were approximately 50 days old, 5.0 cm in height (as measured from the root collar to the apical meristem), with an average caliper of 1.5 mm at the root collar. The pistachio proved to be more difficult to germinate, grow and evaluate. Leaves of pistachio seedlings changed from green to scarlet red when transplanted into liquid media, indicating that seedlings suffered from water stress caused by root damage and slow root replacement. Recovery was gradual, but usually complete when established with water or HCNS. Seedlings used in the initial experiments were about 8 cm tall when transplanted from seedling trays purchased from Agri Development Co. While this proceedure proved to be less satisfactory than direct seeding, it allowed pistachio brackish water testing to proceed without delay. In addition, larger seedlings grown in 41 cm deep by 16 cm diameter containers, which were about 58-60 cm tall, were used in the first solution testing. These seedlings were also purchased from Agri Development Co.

Greenhouse temperatures were maintained at a 70-88°F range (night-day). Ventilation was required frequently during the day (even during the winter), resulting in CO_2 concentrations normally near ambient.

For the liquid tests, seedling root plugs were removed from the 'RL' tubes and soaked for a few minutes in water. Soaking loosened the medium from the roots, which were gently washed with a fine water stream. Primary roots were pruned to 15 cm long to avoid excessive root mass in the tank or channel, to stimulate new root growth, and to facilitate initial root data measurements. Seedlings were then placed in the trough and supported by gently clamping the root collar with styrofoam. This collar allowed the roots to rest freely in the aerated medium or in the trough of flowing solution (NFT). Plants were established for at least 10 days in tap water or HCNS until new healthy white root tips were evident. When plants were ready to receive brackish water treatments, initial plant data were recorded (height, caliper, total weight, and root fresh and weight). Plants used in solid media tests were seeded or rooted and grown or transplanted into RL tubes containing peat-vermiculite or fine silica sand media. All were managed similarly to the procedures described above. Base data on height and caliper plant fresh and dry weight were taken at the beginning of the tests. Asparagus (cv Mary Washington 500), portulaca, and statice were planted in 'RL' tubes containing peat: vermiculite (2:1, v/v). Cuttings of iceplant were rooted under similar conditions. All were well established before the brackish water treatment brackish water screening began.

Plant Data Recorded

Data were normally recorded at the beginning and end of the tests, and in a few cases at intervals during the test. The usual parameters measured were main stem height from the cotyledon scars to the seedling top, caliper at the scars, length and/or number of axillary branches and fresh weight and dry weight of roots and tops. The usual experimental unit measured was three plants per plot, but occasionally single matched plants were sampled at different intervals through the test. At sampling, the plant top was severed at the medium-air interface and the root portion was washed initially in sodium meta phosphate to remove medium from the roots, then with a final wash in deionized water. Fresh weight was recorded on both top and roots after blotting the tissue dry. Dry weights were measured after drying to constant weight at 65°C.

Aerated Hydroponic Solution

Semi-rigid plastic containers, approximately 20 x 35 cm x 18 cm deep were filled with the HCNS to within 2.5 cm of the surface.

A 2-cm thick styrofoam board was cut to fit inside the container top in such a way as to leave 0.5 cm air space above the solution. Equally spaced holes were cut in the styrofoam cover to accommodate eight plants of both afghan pine and pistachio. "Large" sized air pumps plus air stones typically used to aerate aquarium tanks were used to deliver a continuous multibubble air stream. Normally, two pumps were adequate to aerate the containers used in one replicate (6 or 8 containers). Each solution was observed regularly and the air streams were adjusted to visual uniformity. Solutions were normally changed every 10 days. At this time each container was washed with 10 percent sodium hypochlorite solution and the plant roots were vigorously washed under a stream of tap water. At times, roots were soaked in a solution containing a fungicide or bactericide.

In the first solution study conducted from August 17 to September 30, 1985, afghan pines about 15 cm tall and relatively large pistachio seedlings (ready for budding) were cultured in brackish waters with gradient treatments ranging from the HCNS control to 1.0X brackish water. The second aerated solution gradient test, which utilized the best techniques as determined from the first test, began on November 9, 1984. It attempted to evaluate the response of the same two nursery species to the same salinity array. Treatments were not applied until new white brackish roots were abundant on all seedlings. The first preconditioning test began on September 7, 1984, when uniform direct-seeded seedlings were reestablished in water for two weeks. Following production of many white branch roots, the preconditioning treatments began on September 21 and continued for three weeks. Seedlings were exposed to 0.125X, 0.25X, 0.50X, 0.75X and 1.0X brackish water for four weeks.

Because the micro-organism complex problem with its persistent and debilitating effects altered our ability to evaluate liquid hydroponics technique, a study was established to evaluate the control potential usefulness of copper sulfate and 'Agrostrept' for controlling these microorganisms on afghan pine under 0.125x brackish water. After two weeks of establishment, copper sulfate was applied at rates from the recommended one to 16 times that rate.

Nutrient Film Technique (NFT)

The experimental NFT system constructed was a modified version of system described by Cooper (1979). Plant growing channels were formed by convoluting plastic sheeting (black 6-mil polyethylene) laid over a ribbed wooden framework. The channels were 1.2 meters long, 10 cm wide and 7 cm deep draining with a 5 percent slope into 15-liter plastic catchment tubs. Solutions pumped from the catchment tubs to the top of the NFT channels by small submersible electric pumps flowed down the channels and returned to the catchments. The flow pipes were constructed of rigid polyethylene and the flow pipe orifices were semi-rigid PVC.

Black polyethylene plastic sheeting was draped over all surfaces where the flowing brackish water-nutrient solution was exposed to sunlight. The system was capable of recirculating nutrient solution at a rate of 240 = 30 l/hr. At equilibrium, the circulating solution depth in the channels was about 1 cm.

Some evaporation took place, especially at the peak irradiation periods, causing the solution EC to increase. De-ionized water was added to the tubs daily to maintain acceptable concentration ranges. Solution pH was also monitored, and when it rose above 6.5, was adjusted to 6.0 by adding .5 N HCl.

The NFT racks contained eight troughs. Two troughs were dedicated to one treatment, and with four treatments (control, .2X, .4X, .6X), one rack was sufficient to accommodate one replicate. Treatments were arranged in a randomized complete block design with four replicates. While replicates were started at different times (from mid-February to mid-March), established seedlings were exposed to their assigned brackish water treatments for 50 days.

Solid Medium

Gradient Studies: Before testing, seeds or cuttings of the species to be evaluated were grown and/or established in RL tubes containing fine silica sand or peat/vermiculite (2:1, v/v). When large seedling size differences existed at the outset, plants of a similar size were confined to the same block (one block was normally larger than the others). Initial base line data recorded included fresh and dry weight and height for all species and caliper of the tree species. Similar data were recorded periodically through tests on three inner plants of the five per treatment.

Two similar tests were conducted. The first compared afghan pine (*Pinus eldarica*) and pistachio (*Pistachia atlantica*) grown in sand and peat-vermiculite media in the following treatment array: control (HCNS) plus HCNS added to the follow brackish water treatments: .125X, .25X, .5X, .75X and 1X. Seedlings were watered twice daily with the respective solutions. Treatments were arranged in a randomized complete block design with three replicates.

The second test tested four herbaceous salt tolerant species, asparagus (Asparagus officinales), ice plant (Lamprathus spectablis), portulaca (Portulaca grandifolia) and statice (Limonium sinuatum) grown in the peat-vermiculite medium. The same array of brackish water treatments was applied twice on alternate days beginning June 25 and ending July 26, 1985. Double watering resulted in extensive media leaching, but no record was made on the volume applied or leached. Generally, care was taken to avoid watering the foliage. In the first test the foliage was lightly syringed with tap water to remove any saline water. Syringing was not done in the herbaceous species study.

In both tests, the two guard plants in each plot were transplanted directly from the greenhouse to the field on April 14 for the pine and pistachio species and August 9 for the succulent species. The soils were unfertilized silt loam and a sandy loam respectively. Both plots were irrigated once immediately after transplanting. Observation on survival and growth were made in both tests plus height and caliper measurements on the pine and pistachio seedling on August 12 (120 days after transplanting).

Pre-conditioning Study: A replicated test similar to the liquid hydroponics preconditioning study was conducted using a solid medium. Seed was sown January 4, 1985, and the test was initiated February 15. Routine management proceedures, including regular HCNS applications, were maintained prior to testing. Blocks with varying number of plants were first treated with 0.06X, 0.125X and 0.25X brackish water. On subsequent weeks all but six plants (two per replicate) of each species were treated with the next highest brackish water concentration, i.e., 0.06X was increased to 0.125X, 0.125X to 0.25X and 0.25X to 0.50X. The next week the concentration of solution of those plants receiving less than 0.5X treatment was increased again. This weekly stepping process continued for four weeks for the seedlings, which first received the 0.06X level, three weeks for those receiving the 0.125X level and two weeks for those receiving the 0.25X level. By the end of four weeks, the following preconditioning treatments had been established:

1. 0.06X (4 weeks continuous exposure)
2. 0.06X (1 week) 0.125X (3 weeks)
3. 0.06X (1 week), 0.125X (1 week) 0.25X (2 weeks)
4. 0.06X (1 week) 0.125X (1 week) 0.25X (1 week) 0.50X (1 week)
5. 0.125X (4 weeks)
6. 0.125X (1 week) 0.25X (3 weeks)
7. 0.125X (1 week) 0.25X (1 week) 0.50X (2 weeks)
8. 0.25X (4 weeks)
9. 0.25X (1 week) 0.50X (3 weeks)

At the end of four weeks, base line data on length and caliper each plant were recorded. Height and caliper were again recorded May 21, along with fresh and dry weight of roots and tops.

RESULTS

Solutions Culture Root Organism Bacteriogloeae

During testing, an omnipresent root microorganism complex which caused root death and general loss of vigor was particularly acute in brackish water treatments. Roots of both species were coated with a slimy, greyish-brown gelatinous layer, giving species-affected roots an unhealthy and abnormal appearance. The first examination confirmed the presence of pathogen *Fusarium* spp. Subsequent examination detected the presence of bacteria. At the end of the NFT study, another microbiological assay of the root material did not detect the presence of any strongly pathological organisms, but confirmed the presence of opportunistic saprophytes. Saprophytes were most probably feeding on the salt-affected or salt-killed plant roots.

Through the period of testing 'Captan', 'Benlate', 'Ridomil', or copper sulfate as well as 'Agrestrept', were added to the solutions to control root organism. 'Banrot' was first tested, but foaming prevented its use except as a root drench. At times Captan and Ridomil appeared somewhat effective, but full control was never achieved. Washing of all utensils and containers with 'Clorox' (10 percent) did not help. Symptoms continued when plants were cultured with copper sulfate. The solution additions of 'Agrostrept' did not help. New roots were apparent in a few plots within one week, but the response was neither uniform nor lasting.

Mexal et al. (1975) suggest that such conditions could be due to O_2 deficiency induced by low water potential. MacDonald et al. (1985) reported that Phytophthora crytogea infections were greatly increased in chrysanthemum roots subjected to salinity (EC 10-20 mmohs/cm). They suggest that salt stressed roots leaked sugars and amino acids that attracted and stimulated growth of zoospores. It's highly possible that a similar condition occurred in there tests.

Aerated Solution

Within days after the brackish water was applied in the first test, symptoms of a complex of microorganisms (as described above) was evident on the roots. Plant vigor gradually declined and all the afghan pines were dead at the test end (September 30). Pistachio seedlings showed similar symptoms, but were less severely affected. An analysis of pistachio tissue sampled on August 28 showed that phosphorus, potassium, calcium, magnesium, zinc, boron, iron, manganese copper and aluminum were not significantly affected by the brackish water treatments. Only sodium significantly increased in the tissue as its brackish water concentration increased. Tissue concentration were low in control plants (0.19 percent Na), followed by a large increase (0.60 percent Na) at 0.125X concentration and remained at similar levels through 0.50X treatment, after which another large increase occurred at 0.75X (1.10 percent Na).

In the second test new white branch roots were produced on all seedlings before the brackish water treatments began. One week after treatments began the afghan pines showed evidence of the microorganism complex and by two weeks the pines were in an advanced state of decline (neucrotic needles and ultimate death). Roots on a few pine specimens appeared to outgrow the condition and appeared healthy. Pistachio plants appeared more resistant and healthy roots were frequently evident on plants in the 0.25X treatment.

At termination on January 30, 1985, all of the pistachio and only 25 percent of the afghan pine survived in the control treatment. No other pines survived, and 71 and 25 percent of the pistachio seedlings survived in the 0.125X and 0.25X treatments respectively. This spectacular loss of the test pines was in extreme contrast to 80 percent survival of healthy growing companion seedlings that were maintained (as possible replacements) in water throughout the test period. At least part of this attrition was due to loss brackish water induced salt stress.

After three weeks under that preconditioning, pistachio seedlings receiving the final preconditioning brackish water treatments appeared as follows:

Final Solution	Foliage Neucrosis Moderate (lower leaves affected)	Severe (All leaves affected)	Seedlings with white roots
	--------------------	%	--------------------
0.125X	25	--	100
0.25X	100	--	100
0.50X	62	38	38
0.75X	25	75	50
1.0X	12	88	38

Plants in the treatments with higher concentration exhibited more needle death and severely reduced root vigor. After 11 days of exposure of plants pretreated with a final brackish water treatment of 0.50X to 0.75X showed damage symptoms on all plants. Plants pretreated with 0.125X and 0.25X brackish water were rated as good. While seedlings remained alive, most continued in decline. Thus, saline preconditioning appears to have a favorable ameliorating effect in higher saline stress effects. It is doubtful that the three weeks of preconditioning were sufficient to alter morphology, and osmotic regulation is the more likely factor accounting for the enhanced survival associated with preconditioning (Greenway and Mumms 1980). A few seedlings continued to add root and top biomass until the test was terminated. The fact that some specimens persisted indicates that, either the conditions favoring decline were variable or that within the pistachio genetic pool, resistance to the microorganism complex and/or saline stress exists.

Nutrient Film Technique

Introduction of brackish water to the troughs containing established seedlings of afghan pine and pistachio severely reduced the vigor and survival. In the control plots, the mean survival of afghan pine over four replicates was 72 percent and that of pistachio, 32 percent. This declined to 28 percent and 13 percent respectively at 0.2X treatment, 9 and 3 percent at the 0.4X treatment and 3 and 3 percent in the 0.6X treatment. Much of this attrition was due to root micro-organisms. Real growth was normally limited to the control and 0.2X treatments. At the end of the test, afghan control plants gained an average of 11.2 g/plt and that of pistachio 0.6 g/plt. The mean changes in fresh weight under the .2X treatment were 8.8 g/plt for the afghan pine, and there were no surviving pistachio plants.

Isolated instances of plant survival and growth in the two highest brackish water treatments were present in three out of the four blocks. In block 1 treatment (0.4X), one Afghan pine seedling survived and gained 35 percent in top dry weight and 60 percent in root dry weight. Other examples include one pistachio plant in block 3, treatment 0.6X where dry weight increased 27 percent. Another pistachio plant in block 2, treatment (0.6X) which gained more than 7 percent in dry weight. Also, in block 3, a pistachio under the 0.4X regime gained a total of 63 percent in dry weight. In all cases these plants appeared healthy.

Because no pattern of seedling response was noted, it was concluded that genotypic differences determined individual plant tolerances for salinity and/or the root organism complex. Such differences are not unusual among sexually reproduced plants, such as afghan pine and pistachio, but the anomalies were most common for pistachio. Thus, it appears that pistachio is especially suited to selection for saline stress resistance.

Gradient Solid Medium

Seedlings of both species grown in fine silica sand were smaller at the beginning of the test and afghan pine seedling were larger than pistachio (tables 2, 3). Small differences that existed within the initial heights of plants for both species indicates that the plant grading was not

Table 2: Effect of gradient brackish water treatments on growth parameters of Afghan pine. Treatments began on February 14, 1985.

Media Treatment	Brackish Water Treatments	Initial		net change after 32 days	net change after 55 days	
		Height (cm)	Caliper (mm)	Height (cm)	Height (cm)	Caliper (mm)
Peat/verm. (2:1)	Control[1]	7.01	1.50	7.16	11.36	0.83
	0.125X	6.81	1.50	6.31	10.25	0.70
	0.25X	6.63	1.50	6.13	9.43	0.71
	0.50X	6.96	1.53	5.27	9.01	0.83
	0.75X	7.22	1.50	4.28	7.47	0.58
	1.00X	6.82	1.50	4.08	6.93	0.58
Sand	Control[1]	4.13	1.50	5.93	9.38	0.51
	0.125X	4.09	1.50	4.74	7.75	0.50
	0.25X	4.00	1.50	4.70	7.79	0.57
	0.50X	4.23	1.50	3.59	6.48	0.48
	0.75X	4.46	1.50	3.31	5.82	0.40
	1.00X	3.90	1.50	2.10	4.99	0.32
Significance						
Media		**	NS	**	**	**
Solution		**	NS	**	**	*
Media x Solution		NS	NS	NS	NS	NS
LSD (Solution)						
0.05		0.22	--	0.57	0.76	0.15
0.01		0.30	--	0.77	1.02	--

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Table 3: Effect of gradient brackish water treatments on growth parameters of pistachio. Treatments began on February 14, 1985.

Media Treatment	Brackish Water Treatments	Initial		net change after 32 days	net change after 55 days	
		Height (cm)	Caliper (mm)	Height (cm)	Height (cm)	Caliper (mm)
Peat/verm. (2:1)	Control[1]	4.46	1.70	4.63	13.86	0.89
	0.125X	4.05	1.80	5.36	10.32	0.03
	0.25X	4.67	1.67	3.80	7.40	0.90
	0.50X	4.39	1.60	1.91	4.02	0.76
	0.75X	4.93	1.73	0.70	0.90	0.35
	1.00X	4.63	1.63	0.37	-0.25	0.05
Sand	Control[1]	2.16	1.03	3.61	5.82	0.84
	0.125X	2.03	1.07	3.14	4.60	0.66
	0.25X	2.20	1.07	2.49	3.13	0.58
	0.50X	1.97	1.00	1.18	1.82	0.52
	0.75X	2.37	1.00	0.77	0.49	0.22
	1.00X	2.33	1.00	0.13	0.13	-0.03
Signifance						
Media		**	**	**	**	**
Solution		**	NS	**	**	**
Media x Solution		NS	NS	**	**	NS
LSD (Solution) 0.01		0.45	--	0.79	1.96	0.21

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

fully effective. After exposure to brackish water, growth in height was reduced only slightly at relatively low concentrations for both species. Pines tolerated higher salinity levels than pistachio, as evidenced by a major height reduction in growth between 0.25X and 0.5X for pistachio and between 0.5X and 0.75X for pine. Pistachio seedlings cultured with 1.0X brackish water were at least 92 percent shorter than those grown in the control regime at this end of the test. The reduction in pine was less than 50 percent in peat-vermiculite and only slightly higher in the medium sand. The appearances of the plants during the test tended to verify the growth data. Leaf loss, chlorosis and marginal nucrosis symptoms were clearly visible and more severe in pistachio as the brackish concentration increased. Also, some pistachio plants died at the high concentration, but no pines died.

Weight changes reflect the same general pattern as those recorded in height. Afghan pines weight reductions were most severe at concentrations above 0.5X (tables 4, 5, 6). Losses in both root and top weights were approximately proportional. The percentage dry matter of pine did not vary substantially and averaged about 20 percent. The pistachio appeared less resistant to salinity and strong negative response to brackish water occurred above 0.25X (tables 7, 8, 9). The pistachio dry matter percentages at all sampling dates were higher than for afghan pine and generally increased with each sampling date. Low afghan pine percentages are most probably a reflection of the leaf neucrosis and scenescence which became more extensive with prolonged exposure to the higher brackish water treatments increased.

When the medium was washed away exposing seedling roots, bifurcated roots, typical of mycorrhizal infections, were extensive in the afghan pines grown at the 0.75X and 1.0X brackish water concentrations. Experts verified

Table 4. Effect of brackish water treatments on the root and top fresh and dry weights of afghan pine grown in peat-vermiculite (2:1) and fine silica sand media. Treatments began on February 14. Data recorded on March 18, 1985.

Media Treatments	Brackish Water Treatments	Fresh Weight (g)			Dry Weight (g)			
		Roots	Top	Total	Roots	Top	Total	Dry Matter (%)
		--------g/plt--------			--------g/plt--------			
Peat/Ver (2:1)								
	Control[1]	2.46	5.19	7.67	0.31	1.10	1.41	18
	0.125X	2.56	4.92	7.48	0.36	1.10	1.46	20
	0.25X	3.57	4.34	7.91	0.38	0.98	1.36	17
	0.50X	2.34	4.40	6.74	0.27	0.94	1.21	18
	0.75X	2.74	3.96	6.70	0.32	0.95	1.27	19
	1.0X	2.12	3.48	5.60	0.27	0.81	1.08	19
Sand								
	Control[1]	3.04	3.29	6.33	0.28	0.68	0.96	15
	0.125X	2.05	2.87	4.92	0.30	0.68	0.98	20
	0.25X	1.44	2.53	3.97	0.22	0.58	0.80	20
	0.50X	1.90	2.37	4.27	0.25	0.57	0.82	19
	0.75X	1.42	2.25	3.67	0.21	0.57	0.78	21
	1.0X	1.21	1.93	3.14	0.18	0.47	0.65	21

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

	Fresh Roots	Fresh Top	Dry Roots	Dry Top
Significance				
Media	**	**	*	**
Solution	*	**	NS	**
Media x Solution	*	NS	NS	*
LSD (Solution)				
.05	0.48	0.48	--	0.10
.01	---	0.64	--	0.13

Table 5. Effect of brackish water on the root and top fresh and dry weights of afghan pine grown in peat-vermiculite (2:1) and fine silica sand media. Treatments began on February 14. Data recorded on April 10, 1985.

Media Treatments	Brackish Water Treatments	Fresh Weight Roots	Fresh Weight Top	Fresh Weight Total	Dry Weight Roots	Dry Weight Top	Dry Weight Total	Dry Matter (%)
		--------g/plt--------			--------g/plt--------			
Peat/Ver (2:1)								
	Control[1]	4.43	8.60	13.03	0.79	2.00	2.79	21
	0.125X	4.64	10.05	14.69	0.76	2.28	3.04	21
	0.25X	5.19	8.42	13.61	0.64	1.99	2.63	19
	0.50X	4.73	8.25	12.98	0.67	1.97	2.64	20
	0.75X	3.44	5.65	9.09	0.48	1.42	1.90	21
	1.0X	3.45	6.09	9.54	0.49	1.59	2.08	22
Sand								
	Control[1]	3.32	7.31	10.63	0.67	1.79	2.46	23
	0.125X	2.87	4.87	7.74	0.50	1.14	1.64	21
	0.25X	3.20	5.66	8.86	0.56	1.42	1.98	22
	0.50X	2.78	4.79	7.57	0.46	1.16	1.62	21
	0.75X	1.94	3.81	5.75	0.37	0.99	1.38	24
	1.0X	1.47	2.73	4.20	0.26	0.64	0.90	21

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

	Fresh Roots	Fresh Top	Dry Roots	Dry Top
Significance				
Media	**	**	**	**
Solution	**	**	**	**
Media x Solution	NS	NS	NS	NS
LSD (Solution)				
.05	0.95	1.53	0.12	0.32
.01	1.26	2.04	0.15	0.43

Table 6. Effect of brackish water on the root and top fresh and dry weights of afghan pine grown in peat-vermiculite (2:1) and sand media. Treatments began on February 14. Data recorded on April 19, 1985.

Media Treatments	Brackish Water Treatments	Fresh Weight			Dry Weight			Dry Matter (%)
		Roots	Top	Total	Root	Top	Total	
		--------g/plt--------			--------g/plt--------			
Peat/Ver (2:1)								
	Control[1]	4.85	11.70	16.55	1.13	3.45	4.58	28
	0.125X	4.78	11.18	15.96	0.84	3.07	3.91	24
	0.25X	4.96	11.24	16.20	0.92	3.15	4.07	25
	0.50X	5.37	10.84	16.21	0.87	3.01	3.88	24
	0.75X	4.01	8.59	12.60	0.67	2.41	3.08	24
	1.0X	3.32	7.49	10.81	0.57	2.09	2.66	25
Sand								
	Control[1]	3.68	7.82	11.50	0.91	2.42	3.33	29
	0.125X	3.44	6.34	9.78	0.67	1.77	2.44	25
	0.25X	3.20	5.93	9.13	0.60	1.63	2.23	24
	0.50X	2.41	4.66	7.07	0.47	1.31	1.78	25
	0.75X	2.18	3.97	6.15	0.44	1.09	1.53	25
	1.0X	1.27	2.19	3.64	0.25	0.74	0.99	27

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

	Roots	Top	Root	Top
Significance				
Media	**	**	**	**
Solution	**	**	**	**
Media x Solution	NS	NS	NS	NS
LSD (Solution)				
.05	0.86	1.57	0.18	0.48
.01	1.15	2.09	0.23	0.64

Table 7. Effect of brackish water on the root and top fresh and dry weights of pistachio grown in peat-vermiculite (2:1) and sand media. Treatments began on February 14, 1985. Data recorded on March 18, 1985.

Media Treatments	Brackish Water Treatments	Fresh Weight Roots	Fresh Weight Top	Fresh Weight Total	Dry Weight Roots	Dry Weight Top	Dry Weight Total	Dry Matter (%)
		--------g/plt--------			--------g/plt--------			
Peat/Ver (2:1)								
	Control[1]	1.52	3.10	4.62	0.31	1.02	1.33	29
	0.125X	1.65	3.61	5.26	0.35	1.14	1.49	28
	0.25X	1.57	2.28	3.85	0.35	0.72	1.07	28
	0.50X	1.36	2.03	3.39	0.31	0.61	0.92	27
	0.75X	1.29	1.82	3.11	0.31	0.55	0.86	28
	1.0X	1.42	1.27	2.69	0.31	0.43	0.74	28
Sand								
	Control[1]	1.21	1.94	3.15	0.27	0.60	0.87	28
	0.12X	1.06	1.46	2.52	0.25	0.38	0.63	25
	0.25X	0.68	1.25	1.93	0.15	0.35	0.50	26
	0.50X	0.74	1.25	1.99	0.18	0.32	0.50	25
	0.75X	0.67	0.84	1.51	0.15	0.24	0.39	26
	1.0X	0.62	0.59	1.21	0.15	0.19	0.34	28

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Significance	Fresh Roots	Fresh Top	Dry Roots	Dry Top
Media	**	**	**	**
Solution	*	**	NS	**
Media x Solution	*	NS	NS	*

LSD (Solution)
.05
.01

Table 8. Effect of brackish water in the root and top fresh and dry weights of pistachio grown in peat-vermiculite (2:1) and sand media. Treatments began on February 14, 1985. Data recorded 55 days after treatments began.

Media Treatments	Brackish Water Treatments	Fresh Weight			Dry Weight			
		Roots	Top	Total	Roots	Top	Total	Dry Matter
		---------g/plt--------			---------g/plt--------			(%)
Peat/Ver (2:1)								
	Control[1]	3.52	5.56	9.08	0.88	1.88	2.76	30
	0.125X	2.58	4.80	7.38	0.69	1.71	2.40	32
	0.25X	2.54	4.40	6.94	0.53	1.47	2.00	29
	0.50X	1.89	2.85	4.74	0.43	0.92	1.35	28
	0.75X	2.13	2.74	4.87	0.55	0.93	1.48	30
	1.0X	1.19	0.75	1.94	0.35	0.29	0.64	33
Sand								
	Control[1]	1.83	2.28	4.11	0.56	1.02	1.58	38
	0.125X	1.65	2.31	3.96	0.49	0.81	1.30	33
	0.25X	1.95	2.49	4.44	0.47	0.81	1.28	29
	0.50X	2.24	1.53	3.77	0.39	0.50	0.89	24
	0.75X	0.87	0.94	1.81	0.28	0.31	0.59	33
	1.0X	0.52	0.33	0.85	0.13	0.11	0.24	28

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

	Fresh Roots	Fresh Top	Dry Roots	Dry Top
Significance				
Media	**	**	**	**
Solution	**	**	**	**
Media x Solution	NS	NS	NS	NS
LSD (Solution)				
.05	0.53	0.62	0.11	0.18
.01	0.70	0.83	0.14	0.25

Table 9. Effect of brackish water on the root and top fresh and dry weights of pistachio grown in peat-vermiculite (2:1) and sand media. Treatments began on February 14, 1985. Data recorded 55 days after treatments began.

Media Treatments	Brackish Water Treatments	Fresh Weight Roots	Fresh Weight Top	Fresh Weight Total	Dry Weight Roots	Dry Weight Top	Dry Weight Total	Dry Matter (%)
		--------g/plt--------			--------g/plt--------			
Peat/Ver (2:1)								
	Control[1]	2.67	6.51	9.18	0.77	2.58	3.35	36
	0.125X	2.98	5.16	8.14	0.86	1.96	2.82	35
	0.25X	2.88	5.79	8.67	0.86	2.25	3.11	36
	0.50X	1.83	2.81	4.64	0.50	1.01	1.51	33
	0.75X	1.55	1.40	2.95	0.34	0.47	0.81	27
	1.0X	0.88	0.51	1.39	0.20	0.21	0.41	29
Sand								
	Control[1]	2.27	3.28	5.55	0.70	1.27	1.97	35
	0.125X	2.21	3.11	5.32	0.72	1.26	1.98	37
	0.25X	1.71	2.45	4.16	0.48	0.87	1.35	32
	0.50X	1.30	1.49	2.79	0.39	0.54	0.93	33
	0.75X	1.04	1.14	2.18	0.30	0.40	0.70	32
	1.0X	0.32	0.17	0.49	0.07	0.08	0.15	31

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

	Fresh Roots	Fresh Top	Dry Roots	Dry Top
Significance				
Media	**	**	**	**
Solution	**	**	**	**
Media x Solution	NS	NS	NS	NS
LSD (Solution)				
.05	0.43	0.58	0.13	0.24
.01	0.57	0.77	0.17	0.32

that the symptoms were those of a mycorrhizal infection. Apparently the innoculation was naturally available, and the stresses induced by salinization favored natural infection. This finding is consistent with the report of Walker et al. (1983), and it suggests that infecting seedling pines to the culture with brackish water could provide a natural mechanism for moderating adverse effects of salinity on nursery seedlings.

During transplanting of the two guard plants, the root ball integrity was maintained during removal from the 'RL' tube for seedlings in peat-vermiculite, but it tended to break up on sand-grown seedlings. An evaluation after 120 days showed all the seedlings grown in both sand and peat/vermiculite at all brackish water treatments survived. Growth was remarkably good in all cases (table 10). The height and caliper of pistachio increased at the 0.125X brackish water concentration, and then it decreased at higher concentrations. However, brackish water treatments did not substantially affect the height of the slower growing afghan pine. Caliper was not as severely reduced until pistachio was exposed to 0.25X, or afghan pine to 0.50X brackish water concentrations. Height and caliper were generally smaller on those plants grown in sand compared to those grown in vs peat/vermiculite for all brackish water treatments. These data suggest that pistachio rootstock seedlings grown in the greenhouse with brackish water can be planted directly in the field. Growth of the better seedlings was sufficient to produce a plant large enough for budding by late summer.

The chemical properties of media used in the gradient and species study are summarized in table 11. In both sand and peat/vermiculite media, EC and sodium increased as the brackish water concentration increased. In the sand used to grow pistachio, the EC and Na were significantly lower than in the

Table 10: The height and caliper of afghan pine and pistachio produced under varying concentrations of brackish water conditions and outplanted to the field (silt loam) and grown uniformly for 120 days (April 19 to August 17, 1985). The plot received one irrigation on April 19 and only natural rainfall thereafter. Survival was complete, and growth was rated on excellent for all seedlings.

Brackish Water Treatments	Height (cm)				Caliper (mm)			
	Afghan		Pistachio		Afghan		Pistachio	
	Peat/Ver	Sand	Peat/Ver	Sand	Peat/Ver	Sand	Peat/Ver	Sand
Control[1]	26	19	69	57	8.0	6.3	8.0	9.0
0.125X	27	20	91	62	7.3	5.3	11.3	8.3
0.25X	28	19	54	43	7.0	5.3	9.0	6.3
0.50X	27	18	46	38	6.3	5.3	7.3	5.3
0.75X	26	17	51	33	6.3	4.3	7.3	5.7
1.00X	26	20	38	24	5.7	4.3	5.7	4.7

[1] Control plants received HCNS and the brackish water treatment received the salt plus HCNS.

Table 11. Effect of brackish water treatment and nursery species on the characteristics of the solid media at the termination of the brackish water gradient experiment.

Brackish Water Treatments	Afghan Pine				Pistachio			
	Peat/Verm		Sand		Peat/Verm		Sand	
	EC (mmoh/cm)	Na (ppm)	EC (mmoh/cm)	Na (ppm)	EC (mmoh/cm)	Na (ppm)	Ec (mmoh/cm)	Na (ppm)
Control	1.16	1.77	1.37	1.28	1.15	1.93	1.34	3.22
0.125X	3.64	17.37	3.18	13.35	4.20	20.07	3.14	13.23
0.25X	5.56	30.61	4.86	24.45	5.28	32.45	5.37	29.96
0.50X	9.50	59.89	8.82	60.46	8.96	57.22	7.60	49.43
0.75X	12.29	85.22	11.71	87.57	11.37	81.22	10.78	73.94
1.0X	14.05	114.68	16.47	124.81	13.71	110.01	13.82	103.49

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Anova Summary

	P/V		Sand		LSD (Soln)	P/V		Sand	
	EC	Na	EC	Na		EC	Na	EC	Na
Solution	**	**	**	**	.05	1.10	9.38	1.06	11.85
Species	NS	NS	*	@	.01	1.50	12.58	1.42	15.91
Treat X Sp.	NS	NS	@	NS					

sand used to grow afghan pines. Similar, but less extensive, reductions occurred in the peat/vermiculite medium used in producing pistachio seedlings. These data suggest that the natural protective mechanism of pistachio may be by sodium absorption and that for afghan pine by sodium exclusion (Shimose 1973).

The overall growth and horticultural quality of the four succulent species were excellent. Survival was 100 percent and most plants were free of salt stress symptoms. The exception was portulaca at 0.75X and 1.00X treatments, where the leaves were smaller and dimpled and the floral buds opened abnormally. The increase in the main stem growth of asparagus was slight throughout the 30-day test (table 12). However, the multiple secondary shoots originating from the subsurface crown grew extensively during the test. A slight decline in growth occurred when any brackish water salt was added (0.125X), but the sharpest break occurred at the 0.50X treatment for the July 10 measurement date and 0.25X for the July 26 date. Large growth reductions occurred under the 0.75X and 1.00X treatments. The pattern of brackish water induced plant weight reductions was similar to that of height charges, i.e., slight weight reductions occurred when the first salt was added, and then followed by a sharp decline at 0.50X and above brackish water treatments (table 13). However, root weight changes were small and dry weight significantly increased at the 0.50X and 0.75X treatments. The percent of dry matter averaged slightly less than 14 percent and did not vary significantly over the treatment array.

Growth of the iceplant was slower and significant differences were not measured until 30 days after the treatments began (table 14). Growth in the main stem and the lateral branch generally declined as the salinity level

Table 12: Effect of brackish water concentration on the growth of main stem and mean aggregate secondary shoot lengths (new secondary stem growth) of asparagus over three dates after brackish water treatments began on June 26, 1985. Data are mean of 9 plants.

	Stem Length (cm/plt)				
Brackish Water Treatments	Initial Main (June 26)	July 10		July 26	
		Main Stem	Lateral Shoots	Main Stem	Lateral Shoots
Control[1]	11.3	10.3	29.3	12.7	69.0
0.125X	10.0	10.0	26.3	12.0	56.0
0.25X	10.0	11.0	26.3	16.7	49.7
0.50X	10.3	10.3	21.7	11.3	42.7
0.75X	10.6	10.3	15.0	10.3	31.3
1.00X	9.7	10.3	9.7	10.3	20.7
Sign.	NS	NS	**	**	**

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Anova combining date and brackish water main treatments show the Treatment X Date interaction for height to be significant at P 0.01, and for secondary shoots to be significant at P 0.10 (2 dates only).

LSD Height		Probability	
		0.05	0.01
Main Stem	6/26	0.05	0.01
	7/10	---	---
	7/26	3.1	4.4
Lateral Shoots	7/10	11.1	15.7
	7/26	17.0	24.1

Table 13: Effect of brackish water concentration on the fresh and dry weight of roots and shoots of asparagus 30 days after brackish water treatments began on June 26, 1985. Data are the mean of 9 plants.

Brackish Water Treatments	Fresh Weight			Dry Weight			% Dry Matter
	Roots	Shoot	Total	Roots	Shoot	Total	
	g/plt						
Control[1]	2.1	2.3	4.4	0.17	0.45	0.62	14.1
0.125X	2.2	1.9	4.1	0.19	0.35	0.54	13.1
.25X	2.3	1.5	3.8	0.20	0.32	0.52	13.9
.50X	2.4	1.4	3.8	0.23	0.29	0.52	13.0
.75X	2.2	0.9	3.1	0.24	0.19	0.43	13.6
1.00X	1.5	0.6	2.1	0.17	0.14	0.31	14.4
Sign.	*	**	**	*	**	**	NS
LSD							
.05	1.0	0.9	1.7	0.03	0.16	0.23	--
.01	--	1.2	2.3	--	0.22	0.31	--

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Table 14: Effect of brackish water concentration on the growth of main stem and mean aggregate lengths of subsequent new (secondary) stems on iceplant over recorded three dates after brackish water treatments began on June 26, 1985. Data are mean of 9 plants.

Brackish Water Treatments	Initial Length (June 26)	July 10		July 26	
		Main Stem Length	Lateral Shoot Length	Main Stem Length	Lateral Shoot Length
	cm/plt				
Control	2.3	4.7	3.7	10.3	18.0
0.125X	2.3	3.7	2.7	7.3	11.0
0.25X	2.3	4.7	2.0	8.0	8.0
0.50X	2.3	4.3	2.0	7.3	7.0
0.75X	2.0	3.3	1.0	6.0	4.3
1.00X	2.3	3.7	1.3	5.0	3.0
	NS	NS	NS	**	**

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Anova combining date and brackish water treatment show the treatment X Date interaction for height to be significant at P 0.01, and caliper to be significant at P 0.01 (2 dates only).

LSD Height		Probability	
		.05	.01
Main Stem	6/26	--	--
	6/10	--	--
	6/26	1.5	2.2
Lateral Shoots	6/10	--	--
	6/26	4.4	6.2

increased. The most striking decline occurred between the control and the first brackish water treatment (0.125X). While height depression occurred immediately, the plants actually increased in fresh and dry weights at the lower brackish water treatments, and they did not significantly fall below the control seedling levels until the 0.50X treatment was applied (table 15). Root weights were relatively unaffected throughout the brackish water treatment array. The percentage of dry matter increased rather uniformly as the brackish water concentrations increased. The largest increase occurred between the 0.75X and the 1.0X treatments.

The overall growth of portulaca was very rapid, and the salinity treatments did not have a large effect on stem and branch growth until after 30 days of treatment (table 16). At that time, plants in the control through the 0.50X regimes were not significantly different. Then, however, a large reduction occurred above the 0.50X brackish water treatment. Similarly, declines in fresh and dry weight were not large until levels above 0.50X were imposed (table 17). The percentage dry matter increased in approximate control with the larger losses in weight at 0.75X and 1.00X treatments.

The growth of statice was recorded in a different manner because of the rosette type growth habit. The effect of brackish water treatments on the mean length of the largest leaves was not significant on July 10, but increased concentrations of brackish water resulted in regular decline in leaf length after that (table 18). As noted in other species, very small changes occurred in the root weights under increasing concentrations of brackish water (table 19). Top (and total) plant weights when the lowest brackish water treatment (0.125X) was supplied, and continued a gradual decline, which continued throughout the treatment array. The percentage dry matter increased

Table 15: Effect of brackish water concentration on the fresh and dry weight of roots and shoot of iceplant 32 days after brackish water treatments began on June 26, 1985. Data are the mean of 9 plants.

Brackish Water Treatments	Fresh Weight			Dry Weight			Dry % Matter
	Roots	Shoots	Total	Roots	Shoot	Total	
	g/plt						
Control[1]	1.1	15.7	16.8	0.16	0.91	1.07	6.3
0.125X	1.6	15.8	17.4	0.20	1.01	1.21	6.8
.25X	1.5	14.1	15.6	0.19	0.93	1.12	7.2
.50X	1.4	10.9	12.3	0.16	0.78	0.94	7.5
.75X	1.1	8.5	9.6	0.14	0.63	0.77	7.8
1.00X	1.3	8.5	9.8	0.17	0.75	0.92	9.2
Sign.	*	**	**	NS	**	**	**
LSD							
.05	0.5	4.0	4.3	--	0.32	0.38	0.91
.01	--	5.4	5.8	--	0.43	0.50	1.20

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Table 16: Effect of brackish water concentration on the growth of main stem and mean aggregate secondary stem growth of portulaca over three dates after brackish water treatments began on June 26, 1985. Data are mean of 9 plants.

Brackish Water Treatments	Initial Length (July 26)	July 10 Main Stem	July 10 Secondary Shoot	July 26 Main Stem	July 26 Lateral Shoots
	----------	----------	cm/plt	----------	----------
Control	7.0	9.7	31.7	19.0	56.7
.125X	7.0	9.3	29.7	19.0	57.0
.25X	7.0	9.0	29.7	16.3	46.7
.50X	7.0	8.7	28.3	15.7	47.3
.75X	7.0	8.3	23.0	14.0	36.0
1.0X	7.0	8.3	19.3	11.0	25.0
Sign.	NS	NS	@	**	**

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Anova combining data and brackish water treatment show the treatment X Date interactions for height to be significant at P 0.01, and for secondary shoots to be nonsignificant (2 dates only).

LSD Height		Probability 0.10	0.05	0.01
Main Stem	6/26	---	---	---
	7/10	---	---	---
	7/26	---	1.8	2.6
Secondary Shoots				
	7/10	7.8	---	---
	7/26	---	17.1	24.4

Table 17: Effect of brackish water concentration on the fresh and dry weight of roots and shoot of portulaca 30 days after brackish water treatments began on June 26, 1985. Data are the mean of 9 plants.

Brackish Water Treatments	Fresh Weight Roots	Fresh Weight Shoots	Fresh Weight Total	Dry Weight Roots	Dry Weight Shoots	Dry Weight Total	% Dry Matter
	g/plt						
Control	1.8	47.7	49.5	0.22	2.90	3.12	6.3
0.125X	2.1	45.0	47.1	0.21	2.49	2.70	5.8
0.25X	2.2	43.1	45.3	0.22	2.33	2.55	5.6
0.50X	2.2	38.8	41.0	0.20	2.34	2.54	6.3
0.75X	1.6	25.3	26.9	0.15	1.83	1.98	7.4
1.00X	1.2	16.8	18.0	0.11	1.16	1.27	7.0
Sign.	**	**	**	**	**	**	**
LSD							
.05	0.5	4.0	4.3	0.07	0.32	0.38	0.9
.01	0.7	5.4	5.6	0.09	0.43	0.51	1.2

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Table 18: Effect of brackish water concentration on mean length of the largest leaves of statice over two dates after brackish water treatments began on June 26, 1985. Data are mean of 9 plants.

Brackish Water Treatments	Mean leaf Length (cm) (July 10)	(July 26)
Control	8.0	13.3
0.125X	7.0	10.4
0.25X	7.4	9.8
0.50X	7.4	9.6
0.75X	6.6	7.8
1.00X	6.4	7.1
Sign.	NS	**

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

Anova combining date and brackish water treatments show the Treatment X Date interactions for leaf length to be significant at P 0.01.

LSD	Probability 0.05	0.01
6/10	---	---
6/26	2.1	3.0

Table 19: Effect of brackish water concentration on root and top fresh and dry weight of stem statice over 30 days after brackish water treatments began on June 26, 1985. Data are mean of 9 plants.

Brackish Water Treatments	Fresh Weight Roots	Fresh Weight Shoot	Fresh Weight Total	Dry Weight Roots	Dry Weight Shoots	Dry Weight Total	% Dry Matter
	g/plt						
Control[1]	2.9	17.4	20.3	0.36	1.62	1.98	9.7
0.125X	3.9	14.8	18.7	0.40	1.48	1.88	10.1
0.25X	3.8	13.3	17.1	0.40	1.41	1.81	10.6
0.50X	3.7	10.8	14.5	0.37	1.28	1.65	11.4
0.75X	3.1	9.3	12.3	0.32	1.14	1.46	11.8
1.00X	2.4	7.7	10.1	0.29	1.13	1.42	14.1
Sign.	**	**	**	@	**	**	**
LSD							
.10	--			0.10			
.05	1.4	3.6	4.4	0.10	0.41	6.52	1.6
.01	1.9	4.8	5.8	--	0.54	0.69	2.1

[1] Control plants received HCNS and the brackish water treatments contained the salts plus HCNS.

gradually for the control to the 0.75X treatment level, followed by a large, 2 percent, increase at 1.0X level.

Preconditioning Study

The results of the preconditioning afghan pines grown in a solid medium (peat/vermiculite) are summarized in table 20. All growth measures of afghan pine seedlings produced over 28 days (the period of preconditioning) and 68 days of uniform exposure to 0.75X brackish water were not significantly different. When the changes from day 28 to day 96 were evaluated, growth of those plants under continous 0.06X brackish water were most severely affected and those conditioned to the higher levels (0.25X and 0.5X) grew best under the subsequent 0.75X brackish water treatment applied to all seedlings. Caliper changes in response to preconditioning pines were approximately similar.

Changes in pistachio growth parameters were significant (table 21). In most cases the best growth occurred at the 0.06X preconditioning treatment and declined with prolonged exposures to the higher levels of preconditioning brackish water. Net height changes (table 22) generally support these conclusions with a few exceptions.

Results are generally supportive of the idea that some species benefit from exposure to moderately saline conditions before they are exposed to more severe saline stress. Positive adjustments attributed to preconditioning effects include changes in morphology (thicker cuticle, fewer stomata, smaller leaves) and increases is cell osmotic potential (Greenway and Mumms 1980). The preconditioning benefits noted here were relatively small, but they definitely favored the reasonable conclusion that gradually exposing afghan pine to increasing levels of brackish water would favor continued normal growth.

Table 20: Effect of brackish water preconditioning treatments on growth of Afghan pine (Pinus eldarica) when exposed to 0.75X treatment for 68 days. Preconditioning began on February 14, 1985 and continued for 4 weeks.

Preconditioning Treatments (Number)	HEIGHT (cm)	CALIPER (mm)	Fresh weight (g) SHOOT	Fresh weight (g) ROOT	Fresh weight (g) TOTAL PLANT	Dry weight (g) SHOOT	Dry weight (g) ROOT	Dry weight (g) TOTAL PLANT
0.06X (1)	10.00	2.97	5.60	2.64	8.24	1.32	0.62	1.94
0.12X (2)	10.83	3.28	7.69	3.79	11.48	1.78	0.78	2.57
0.25X (3)	12.33	3.72	8.56	3.89	12.45	1.99	0.68	2.67
0.50X (4)	12.17	3.83	8.77	4.20	12.97	2.19	0.79	2.98
0.12X (5)	11.83	3.68	8.20	4.30	12.50	1.97	0.79	2.77
0.25X (6)	10.83	3.60	7.22	3.85	11.07	1.79	0.72	2.51
0.50X (7)	9.25	3.08	6.20	2.97	9.17	1.56	0.53	2.09
0.25X (8)	10.00	3.73	7.43	3.74	11.17	1.66	0.68	2.34
0.50X (9)	9.75	3.77	8.00	4.30	12.30	1.91	0.81	2.72
SIGNIFICANCE	NS	NS	NS	@	@	NS	NS	NS
LSD .10	--	--	--	0.88	2.63	--	--	--
LSD .05	--	--	--	--	--	--	--	--
LSD .01	--	--	--	--	--	--	--	--

NS not significant
@ significant at P 0.10 level of significance

Table 21: Effect of brackish water preconditioning treatments on growth of pistachio (Pistachia atlantica) when exposed to 0.75X treatment for 68 days. Preconditioning began on February 14, 1985 and continued 4 weeks.

Preconditioning Treatments (number)		HEIGHT (cm)	CALIPER (mm)	Fresh Weight (g)			Dry Weight (g)		
				SHOOT	ROOT	TOTAL PLANT	SHOOT	ROOT	TOTAL PLANT
0.06X (1)	8.33	3.10	3.50	2.02	5.52	0.88	0.50	1.38	
0.12X (2)	5.25	2.60	0.79	1.53	2.32	0.25	0.37	0.62	
0.25X (3)	4.92	2.60	1.11	1.32	2.43	0.38	0.34	0.73	
0.50X (4)	5.92	2.65	1.24	1.28	2.51	0.41	0.33	0.73	
0.12X (5)	5.17	2.77	1.30	1.46	2.75	0.43	0.37	0.80	
0.25X (6)	4.17	2.83	1.29	1.68	2.96	0.47	0.44	0.91	
0.50X (7)	3.75	2.32	0.83	1.23	2.06	0.32	0.32	0.63	
0.25X (8)	4.50	2.85	1.19	1.45	2.64	0.46	0.39	0.84	
0.50X (9)	4.41	2.50	1.25	1.19	2.45	0.45	0.33	0.79	
SIGNIFICANCE	**	*	**	@	*	*	@	@	
LSD .10	1.84	0.45	1.26	0.51	1.72	0.31	0.11	0.41	
LSD .05	2.34	0.58	1.51		2.06	0.38	--	--	
LSD .01	3.68	--	2.02	--	--	--	--	--	

@ significant at P 0.10 level of significance
* significant at P 0.05 level of significance
** significant at P 0.01 level of significance

Table 22: Effect of brackish water preconditioning treatments on growth of afghan pine & pistachio. Values indicate net increases in height and caliper from day 28 to day 96.

Preconditioning Treatments (number)	Afghan Pine		PISTACHIO	
	HEIGHT (cm)	CALIPER (mm)	HEIGHT (cm)	CALIPER (mm)
0.06x (1)	2.80	1.03	1.73	1.15
0.12x (2)	3.92	1.48	0.15	0.68
0.25x (3)	5.00	1.78	0.07	0.63
0.50x (4)	5.33	1.95	1.58	0.62
0.12x (5)	4.83	1.90	0.53	0.82
0.25x (6)	4.75	1.83	0.60	0.90
0.50x (7)	3.68	1.40	0.25	0.42
0.25x (8)	4.42	2.03	0.38	0.88
0.50x (9)	4.17	1.93	0.80	0.70
SIGNIFICANCE	@	*	**	*
LSD .10	1.44	0.43	1.05	0.35
LSD .05	---	0.52	1.26	0.42
LSD .01	---	---	1.69	---

@ significant at P 0.10 level of significance
* significant at P 0.05 level of significance
** significant at P 0.01 level of significance

DISCUSSION AND CONCLUSIONS

The debilitating effects of microorganism growing on saline stressed roots limits the value of liquid hydroponic culture for culturing nursery plants. These effects appear to be a result of root salinization (McDonald et al. 1985) and possibly relates to lack of O_2 in the root environment (Mexal et al. 1975). Afghan pine was more susceptible to the salinity-microorganism complex than the pistachio. This finding makes the pistachio appear to be more saline tolerant. Also, pistachio demonstrated apparent genetic resistance to salinity and/or the microorganism complex. Good quality root and top growth occurred in the 0.60X level (page 18) and 0.75X (page 41) brackish water levels. While chemical control of the organisms maybe possible, salinity establishes favorable conditions for microorganism expression, and even an effective control program would most probably have to be administrated regularly.

Well aerated solid media, such as peat/vermiculite, provide excellent growing conditions when brackish water is used to culture nursery seedlings. Survival was excellent, and growth quality was good. In many cases, the growth rate was equal to that of the controls. This result was not fully expected because the matric potential of a solid medium does reduce water potential compared to liquid, suggesting that less growth would result. Apparently, the regular moist conditions achieved, when the properly medium aerated, is favorable under salinizing conditions.

The effectiveness of the solid medium-brackish water system as a method for producing nursery stock was further verified by the 100 percent survival of transplanted pistachio, afghan pine seedlings and all the succulents (except iceplant) after only one flood irrigation. In addition, growth of both pines and pistachio was excellent.

The relatively high incidence of mycorrhizal fungal infection in the afghan pine at the high brackish water levels was not expected. The infection suggests that one investigative avenue for future research should be to compare the response of mycorrhizal infected to the brackish water array. Existing evidence suggests that the presence of a mycorrhizal fungis can reduce plant stress caused by salinity or drought (Walker et al. 1983; Foster and Sands 1977; Hirrel and Gerdemann 1980).

Reduction in root weights caused by brackish water were less than top weight reductions in three tests. This finding is consistent with the generalized effects of salinity (Schwary 1985). One exception is those crops whose economic yield is produced below ground. Asparagus (a crop with a storage root) may fall under the latter category, but the root growth was also less affected. It is probable that the seedling affects are maximum ones because young plants are reported to be more sensitive to salinization than older plants of the same species (Schwary 1985).

One possible alternative use for brackish water in nursery production would be for growth control. If seedlings grow too fast, if weather delays planting, or if plant quality is poor (too succulent), it would be possible slow growth and/or increase quality by applying brackish water (for example, 0.50X or 0.75X) to tolerant species. In results reported here growth was slowed without deterimentally affecting the appearance or subsequent survival after outplanting. Such a procedure probably would be limited to salt tolerant species such as those tested here.

The results of plant size (height, branch length) and weight show that the change induced by brackish water occur in approximate concert. Thus, non destructive measures of the plant would give an adequate estimate of the total response. These measures are also reliable measures of the marketability of nursery seedlings. Most nursery seedlings are sold or described by height and/or caliper. Similarly, transplants produced from seed are sold on size and attractiveness.

The results reported here are encouraging, but growth was delayed under moderately high saline conditions. This is consistent with the general effects of salinity on plants (Schwary 1985, Greenway and Mumms 1980). Assuming that the market acceptability of nursery stock is determined by size and appearance, one would need to schedule more time to produce salable material. Increasing the greenhouse resident time for a crop increases the direct and indirect costs. Production costs are neither absolute nor easily available, but the 1984-85 energy costs (natural gas, electricity) in a Las Cruces greenhouse were $4,550.00 per acre per month, or approximately 0.5¢ per seeding-month. If labor and expendible costs are comparable, the total costs would total 1.0¢/seedling month. These costs may appear relatively small, but if prolongation of the growth time reduces the number of production cycles possible in a facility, capital costs for constructing added growing space could double or even triple the production costs for using brackish water. The problem of economics in brackish water seedling production are not insurmountable, but it must be addressed.

The reason for the slower growth for saline stressed plants is not fully agreed upon, but several theories center on the lack of carbon energy to adequately support the essential processes. For example, Schwary (1985) reports the maintenance respiration - the energy required to maintain the normal plant functions - is as much as 30 percent greater for salinized plants compared to nonsalinized ones because of the added energy required to compartmentalize or secrete the excess salts. Another theory is that salinity stress reduces stomatal aperature (which, in turn, reduced CO_2 assimilation) causes a reduced rate of photosynthesis and low carbon energy production Schwarz (1984) reports that aerial CO_2 fertilization overcame the assimilate shortages in saline resistant plants groups. Normal growth was restored.

In tests by Walker and Dounton (1982) photosynthesis of salinized perennial horticultural plants was reduced. In addition to increased stomatal resistance, they report an increase of photorespiration. Added CO_2 could shift the activity of rubisco enzyme from the oxygenase to the carboxyolase form. Thus it may be reasonable to expect that salinized nursery stock which were with CO_2, enriched could be grown within an acceptable time schedule.

Growth of salinized plants is also reported to be better when they were grown under high relative humidity conditions (O'Leary 1975). This observation is consistent with the maintenance respiration theory because the resistance to CO_2 absorption would be less under the high relative humidity (low plant stress) conditions. Thus, high humidity, CO_2 enriched environments may restore growth rates to normal levels or allow for the use of higher saline concentration.

The results show that growing nursery seedlings brackish water (up to an EC of 24 mmhos/cm) is possible. However, growth rates decline, and this could increase the production costs and perhaps productivity. The use of newer technology in conjunction with brackish water (mist cooling, elevated relative humidity, CO_2 enrichment), could further reduce costs by restoring normal growth rates.

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Appendix A
Roswell Test Facility Brackish Water Analysis
February 24, 1981

	Mg/l	Meg/l		Mg/l
Sodium (Na)	4600	200.08	Silica (SiO_2)	13.6
Potassium (K)	24	.61	Dis. Solids, Calc.	14,222
Calcium (Ca)	534	26.65	pH	7.63
Magnesium (Mg)	150	12.34	Total Hardness ($CaCO_3$)	1,950
Chloride (Cl)	7174	202.51	Chlorine Free (Cl_2)	1.15
Sulfate (SO_4)	1532	31.90	Manganese (Mn)	0.02
Bicarbonate ($11CO_3$)	203	3.30	Copper (Cu)	-0-
Carbonate (CO_3)			Zinc (Zn)	.04
Iron, Total (Fe)	.42		Phosphate Total (PO_4)	-0-
Iron, Ferrous (Fe++)	-0-	-0-		
Iron, Ferric (Fe+++)	.42			

Conductivity (25.0°C) 22100