UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL SCIENCES

This is to certify that the format and quality of presentation of the special project submitted by

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As one of the requirements for the degree of

Master of Science

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11/21/2007
Rev: 6/18/2008

Urban greening: low maintenance planters as a means for urban residents to participate in greening initiatives.

Janet Rizner Backs...

Abstract

The benefits of reconnecting humans with nature are becoming increasingly apparent. Many urban areas are taking an active role in making this happen, whether it be through green spaces, urban farmers' markets or garden plots. This paper describes an experiment designed to test an inexpensive planter system that can be used by urban residents in greening rooftops, balconies and patios. The emphasis in design was on inexpensive planter construction, low seasonal maintenance requirements, and ease of replacement of plant material. Additionally, four plant species were tested for survival over one year within the core area of Chicago. The planters recycled natural rainfall and required no additional watering after setup through the growing season. Plant growth and mortality over the summer varied, as did over winter survival. Surface and soil temperature comparisons through the winter season show that this design provided little insulating effect and suggest that a modification is needed if plants are expected to survive through the temperature minimums experienced in this study.

Index words: urban greening, urban planters, container plants, *Rhus copallina* L., blue rug juniper, 'Autumn Joy' sedum, little bluestem, CIPS
Species used in this study: *Rhus copallina* L. 'Prairie Flame', flameleaf sumac; *Juniperus horizontalis* Moench 'Blue Rug', blue rug juniper; *Sedum spectabile* Boreau 'Autumn Joy', showy stonecrop; *Schizachyrium scoparium* (Michx.) Nash var. scoparium, little bluestem.
Chemicals used in this study: Osmocote® classic 14-14-14 slow release fertilizer

Significance to the Nursery Industry

Creating rooftop, balcony and patio gardens in urban areas has environmental, economic, social and aesthetic benefits. As cities develop policies to address urban issues by making use of the positive effects of green environments, planters can be included as a way for citizens to participate. Reasonably priced ways of creating and maintaining plantings are needed to make the concept appealing and affordable to people with limited budgets, time, and horticultural expertise. This study examines how cost-effective planters can be used to reduce water consumption and runoff, add to a green presence and provide an easy way for urban dwellers to green their surroundings. In addition, it tests specific plant species within various urban settings. The test plant material was chosen to include woody deciduous and conifer species, a native perennial grass, and a showy perennial sedum. The test species were selected based on known adaptability to stresses that would normally be experienced in the experimental sites, specifically water stress and light tolerance, with a native range comparable to northern Illinois[1,2,3,4] and potential adaptability to container planting[5]. "City plants must contend with tremendous biological, physical, and chemical stresses: too much water or too little; temperatures too cold or too hot; polluted air, water, and soil; pests and diseases." [6] At the same time they play an integral role in securing the many benefits of environmentally friendly urban designs[7]; this study seeks to add to the body of knowledge defining adaptability and viability of plant species within cities.

Introduction

Rooftop and container gardening has been practiced in both Eastern and Western cultures since the Babylonian civilization.[8] In recent times, European countries have taken a leading role in designing and in some cases mandating architecture to include green space, often on rooftops, balconies, and even on facades of structures.[9] In the United States the impetus to incorporate green spaces in city planning has been increasing as urbanization and suburbanization expand and affect natural processes such as water runoff and heat distribution.[10]

The advantages of urban 'greening' are well documented. Among ecological consequences, vegetation can filter airborne pollutants, provide sound buffering, and reduce rainfall runoff; plants contribute to carbon sequestration[11]; and urban trees remove significant amounts of pollutants through in-leaf usage and interception.[12] Economically, 'heat-island' effects caused by reflections off buildings and streets are ameliorated, resulting in energy savings due to reductions in heating and air conditioning expense. A study conducted in Chicago, monitored the effects of including shade trees, reflective roofs, reflective pavements and urban vegetation on reducing energy costs of cooling, lowering surface air temperature, reducing CO^2 and improving air quality. It found a dual positive result in saving money while improving the environmental quality of the city.[13] While social and aesthetic effects may be more difficult to quantify, studies in such diverse areas as surgical recovery rates and reduced costs of anti-social behavior have been conducted.[14] In a study of surgery patients put in rooms with views of trees versus a view of a brick wall, it was found that tree viewers had shorter stays, required less moderate or strong pain medication, had fewer negative evaluations by nursing staff and slightly lower numbers of post-surgical complications.[15] Difficult to quantify, but not insignificant is the concept that '...there is the potential transformative value of increasing people's appreciation of beauty, by making available some beauty for them to appreciate.'[16]

The study described in this paper was conducted at sites within the 'heat-island' of Chicago, specifically to test low-maintenance plant containers and selected species in a realistic urban setting. Conducting research in large city settings has its special demands. Metropolitan infrastructures, buildings, governmental and private ownership of property, population use, and safety questions all have an impact on experiments. Even aesthetics must be accommodated as the research sites may be in public space. Finding support can be an additional challenge. Scientific rigor must be maintained, while dealing with a lack of complete freedom in design and control of experiment installations.[17]

This is, however, the reality of the urban environment. It is a landscape ecosystem that includes humans.[18, 19] Studying it in a laboratory removes it from the "complex mosaic of biological and physical patches in a matrix of infrastructure, human organizations, and social institutions..."[20] which defines the urban landscape. Although "...urbanized areas cover only approximately 1% to 6% of Earth's surface, yet they have extraordinarily large ecological 'footprints' and complex, powerful, and often indirect effects on ecosystems."[21] In addition to the traditional image of cities as economic hubs, they are global ecological driving forces.[22] The challenge is to incorporate ecological research into all of this and ultimately to include scientific study as an integral part of policy decisions in a dynamic way.

Materials and Methods

CIPS technique

The closed insulated pallet system (CIPS) as originally designed by Oregon State University [23] is a closed system in which plants are sealed into a box with the intent of recycling water and nutrients. Roots and medium are held in pouches made of permeable spunbound polypropylene treated with copper latex solution from which wicks extend into a water reservoir. Water uptake is intended to be through capillary action and is plant-driven. Shoots are sealed in with expanding foam as they extend through the lid. Fertilizer can either be added directly to the planting medium, or introduced through a fertilizer reservoir. This system has the benefit of reducing water and fertilizer input and resulting discharge. Because the overall containers are insulated, temperature extremes are prevented. It facilitates pest management and reduces weed problems and maintenance costs.

Tests have shown that this system can lessen the need for pesticide. Because uptake of water and fertilizer is plant-driven, plants with diverse requirements can flourish within the same pouch. With CIPS '... plants can be grown with 10% of the water and fertilizer applied with sprinkler irrigation of open containers'. [24] In a comparison study of tomato cultivars in CIPS and an open container system using different water qualities, growth and yield was greater using CIPS in both cases studied. [25]

Modified CIPS model

Containers constructed for this study, while based on the original CIPS construction, differed in some significant ways: shoots were not sealed to the lids with the result that an open collar area around the stems allowed rain water to enter; two shunts were added to each planter at specific heights from the ground to drain excess water and maintain reservoir levels; lids were sealed to the edges of the planters with foam and were then covered with burlap for aesthetic reasons; the pouches were of non-woven fabric grow bags with small pored sides which inhibit root growth and non-porous bottoms; two wicks were crossed through slits cut on opposite sides of the root-retardant pouches which held the plants, as opposed to the CIPS system in which the wicks are outside the pouches; pouches were set in aquatic baskets for support and rested on additional aquatic baskets to hold them above reservoir levels; no additional insulation was added to the planters.

Materials

- Planters
  Small: Square Flute Planter Clay 12 in Akro 12/cs 74-212 AKRO-MILS DP212CL. Outside: 12-1/2" Inside: 10-3/4" Height: 10-5/8".
  Medium: Terra Style Square Plntr Terra 20" in Akr 3/cs 75-93320TC AKRO-MILS 933201C. Outside: 20" Inside: 20" Height: 17-5/8".
  Large: Terra Style Round Plntr Terra 24 in Akr 4/cs 75-93025TC AKRO-MILS 93025TC. Outside: 24" Inside: 20" Height: 20"
- Aquatic baskets: black, mesh-type plastic baskets
  For pouch framework:
  Small: 9"L x 9"W x5"D
  Med: 11'L x 11"W x 7"D
  Large: 14"L x 14"W x 10"D
  For use as support of pouch framework:
  Small: 4"L x 4"W x 4"D
  Med/Large: 11"L x 11"W x 7"D
- Root retardant bags: tough bottom Grow Bags
  Small: 10" diameter

Med: 14" diameter
Large: 18" diameter

- Wicks: ¼ inch batting material
  2 each for small: 3" x 17"
  2 each for medium: 3" x 28"
  2 each for large: 3" x 30"
- Drains: ½" 90 degree copper elbows
- Plugs: PVC 'male adapters' and caps
  Small: ½ inch
  Med: 1 inch
  Large: 1 ¼ inch
- Insulation: FOAMULAR Insulation from Owens Corning 1" thickness.
- Foam sealant: 'Great Stuff' Insulating Foam Sealant

Data sensors

Four Onset HOBO Pro Temp/Temp External Data Loggers (#H08-031-08) were used to track surface and soil (in planter) temperatures.

Structural mix

Components of the planting mix are detailed in a research grant proposal entitled 'A Container System to Increase Success of Street/Sidewalk Plantings'[26].

Fertilizer

Source: Osmocote® classic 14-14-14 slow release fertilizer.

Plant material

Rhus copallina L. 'Prairie Flame', flameleaf sumac; *Juniperus horizontalis* Moench 'Blue Rug', blue rug juniper; *Sedum spectabile* Boreau 'Autumn Joy', showy stonecrop; *Schizachyrium scoparium* (Michx.) Nash var. scoparium, little bluestem.

Construction

Two holes were drilled on opposite sides of each planter at water reservoir height levels: small planter at 8.26 cm (3.25 in), medium planter at 13.34 cm (5.25 in) and large planter at 15.88 cm (6.25 in). Drains were inserted into each hole. Insulation was cut to fit container tops based on inside dimensions, then cut in half for ease of placement, and a central opening was cut in each set for shoots: small planter approximately 9 x 9 cm (3.5 x 3.5 in), medium planter approximately 28 x 28 cm (11 x 11 in) to accommodate the juniper spread and large planter approximately 11x 11 cm (4.5 x 4.5 in). A hole was drilled in each top and a capped plug inserted through which water measurements and watering were conducted. Four slits were made at the bottom of each plant pouch and wicking material was placed in a cross pattern through the slits, with wicks long enough to cross through the pouch and reach the container bottoms: small planter wicks 7.62 cm by 43.18 cm (3 in by 17 in), medium planter wicks 7.62 cm by 71.12 cm (3 in by 28 in), and large planter wicks 7.62 cm by 76.20 cm (3 in x 30 in). Pouches were placed in supporting aquatic baskets. Additional aquatic baskets were inverted and placed on the bottom of the planters to raise the plant pouches above water reservoir levels. Roots of plants were washed of original planting mix, trimmed as necessary, and planted in structural planting mix within the pouches. Planting mix was compressed and watered to establish capillary action. The aquatic baskets containing pouches and plants were placed on top of the bottom support baskets. The insulation lids were placed around the extending plant shoots. Lids were sealed with foam to sides of containers and along cuts in lids. Burlap was attached to lids as an aesthetic addition. Each non-control site was set up with 6 replications each of *R. copallina* 'Prairie Flame' in large containers, *J. horizontalis* 'Blue Rug' in medium containers, *S. scoparium* in the small containers, and *S. spectabile* 'Autumn Joy' in small containers. A set of comparable containers, but without the modified CIPS system, was planted with the plant species as a control, and an additional set of plant species was planted directly in the ground as a second control. Fertilizer was top-dressed around each plant in the following amounts: small containers 5.176g, medium containers 9.784g, large containers 34.494g. After planters were set up at the sites, the water reservoirs in the system planters were filled until water flowed from the drains. See schematic diagram Diag.1. HOBO data loggers were set up at one *J.horizontalis* planter at each of four sites: GS, CS, OS and GN. The logger was placed on the surface next to the planter to measure surface temperature and the external soil temperature probe was inserted into the planting mix to measure soil temperature.

Sites

Each site as noted below was set up with 6 replications of each of the test species. At Site SS, plants were placed directly into the ground. At Site NS, plants were placed into planters without the special planter system. At Sites GS, CS, and OS, plants were in planters with the modified CIPS system.

Description of factors at sites

Site 1-3 (GS,NS,SS)

Location: Garfield Park Conservatory grounds, 300 N. Central Park Avenue, Chicago
These are ground level sites adjacent to greenhouses and surrounded by park environment. The planters were located on a surface of crushed light-colored stone. Site GS is protected by its location between greenhouses, which result in early morning and late afternoon shade. All sites are open to wildlife, including rabbits, raccoons and squirrels. Sites SS and NS are watered as part of normal park maintenance. Site GS watering is controlled as part of the experiment.

Site 4 (CS)

Location: Chicago Center for Green Technology (CCGT), 445 North Sacramento Blvd., Chicago
This is a ground level site located on mulched surface. The surface simulates a patio or street-side environment. The site receives late afternoon shade from a building to the west. This site is a recovered brownfield and is located next to a railroad yard. It is subject to industrial pollution.

Site 5 (OS)

Location: OWP/P, 111 W. Washington Street, Chicago
This site is located on a patio on the 22nd floor of a building with exposure on north and east. It faces north overlooking the rooftop of Chicago City Hall. Planters were located on a concrete surface. There is some shading by adjacent buildings on south and east, which is typical of a city location. The location is in the Chicago Loop with buildings surrounding it. Buildings on north and east are of lower elevation. The building on the same block to south is of higher elevation. Buildings on east and west are across streets. The site receives some shade during the day, but buildings on north and east are lower and do not shade it completely. It is open to northerly winds.

Experiments

<u>Experiment 1</u>: *Do plant containers constructed using the modified CIPS model provide a low-maintenance planter option for urban settings over a Chicago growing season?*
Measurements used to determine the feasibility of the reservoir container system were 1) planter system reservoirs levels, 2) temperature and rainfall data, and 3) surface and soil temperatures. To test whether the containers' reservoirs maintained a sufficient water supply over a Chicago growing season, water levels in each container at the sites set up with the modified system planters (GS, CS, OS) were measured every two weeks from June 9 through October 9. Temperature and rainfall measurements for this period were selected to show high and low ambient temperatures and the rainfall pattern over this period of time. Two weather stations were used for temperature and rainfall measurements in order to provide weather data as near to the sites as possible. Data from the CCGT station was provided by MWH Americas, Inc. This station was located at the CS site and was approximately 1.2 mi from the GS site. Permission to use data from Weather Underground station KILCHICA44 in the West Loop was granted by NOAA. This station was approximately 0.5 mi from the OS site. HOBO sensor data giving surface and soil temperatures was downloaded at the time of water level measurements.

<u>Experiment 2</u>: *Within a variety of urban settings, do selected plant species survive and grow using the modified CIPS planter system over a Chicago growing season?*
Delta measurements from setup to the end of the growing season, in addition to plant mortality rates, were used to determine adaptability and success of plants under varying treatments for one growing season. Measurements were averaged for all plants at a site. The following measurements were used: for *R. copallina,* change in twig elongation of a flagged stem and total caliper width for all stems on the plant; for *J. horizontalis*, change in maximum spread; for *S.spectabile,* change in stem count and change in height; and for *S.scoparium* change in plug caliper width and change in height. Mortality rate through the growing season was tracked for each set of plants. In addition, qualitative descriptions of insect activity, disease, and site condition and stresses, were used to complete the evaluation.

<u>Experiment 3</u>: Do plant containers designed using the modified CIPS model allow plants to survive over a Chicago winter season?
Over winter success was determined by plant survival and temperature measurements to determine the insulating effects of the containers as designed.

<u>Experiment 4</u>: *Within a variety of urban settings, do selected plant species survive a Chicago winter season in the modified CIPS systems?*
Over winter success was determined by plant survival from time of last growing season measurements in early October of 2006 to site take downs in late May 2007.

Results and Discussion

For purposes of this discussion, temperature descriptions will be as follows: *ambient* – weather station data, *surface* – sensor data taken at ground level among planter setups, and *soil* – sensor data taken within planting medium.

Experiment 1: *Do plant containers constructed using the modified CIPS model provide a low-maintenance planter option for urban settings over a Chicago growing season?* The containers successfully provided a low-maintenance planter option for the selected species through the growing season observed. After the initial setup and watering, which included refill of one planter (S1) at CS and six planters (C1-6) at GS on 7/19, rainfall replenished the reservoirs through the remainder of the growing season. Temperatures peaked in early August. While water reservoir levels dropped at that time, rainfall, which occurred fairly regularly this growing season, was sufficient to replenish them. This was true at all sites (Fig.1). (See Appendix I, Fig.I-1a through I-2b, for detailed reservoir levels through the growing season, as well as ambient temperatures and rainfall.)

HOBO data showed that the containers in which there were internal sensors provided some temperature amelioration between surface and soil temperatures as seen in the examples shown for the period of maximum temperatures at each site (Fig.2). (See Appendix I, Fig.I-3a through I-3c, for detailed comparisons of surface and soil maximum temperatures at all sites through the growing season.)

Table 1 shows the water consumption for all *R.copallina* plants at the CS site. This example confirms the pull of water by live plants from the reservoirs. At this site, plants D3 and D5 died early in the growing season (Fig.7a) and from that point on, water reservoirs showed no drop in levels for these plants.

Experiment 2: *Within a variety of urban settings, do selected plant species survive and grow using the modified CIPS planter system over a Chicago growing season?* Although because of the ready supply of water, growth and survival rates were expected to be greater for plants in the modified CIPS systems than in the non-system or soil plots, this was not always true for a variety of reasons.

For *R.copallina* (Fig.3a-b) it was indeed the case. Average stem elongation on flagged stems was greater for the sites set up with modified CIPS planters than for either the non-system planter or the soil control sites. Total stem diameters showed a similar pattern. There was a reduction in overall stem numbers by 1 at CS, 2 at OS, and 2 at SS, which affects the total average stem diameter measurements. Looking at mortality (Fig.7a), two plants at CS and one plant at OS died during the growing season. Although there was some early mortality, over the season survival rates were high at all sites.

J.horizontalis (Fig.4a) showed a reduction in overall width at all sites with the exception of CS and SS. This may be partly attributable to the need to cut back their root balls by approximately 1/3 at the time of construction in order to fit them into the root bags. In addition, at GS there was a planter damaged when a raccoon fell into it. However, over the whole season (Fig.7b), they showed the greatest survival rate of any species tested.

While *S.spectabile* showed a general decrease in number of stems over the growing season (Fig.5a), all sites with the exception of OS showed increases in plant height (Fig.5b). Some of the reduction in stem count can be attributed to plants going dormant at the end of the growing season. Loss of plants at OS (Fig.7c) was the result of a severe storm in mid-season during which the *S.spectabile* and *S.scoparium* (see below) were battered by ornamental grasses in nearby decorative planters.

Plug diameters of *S.scoparium* (Fig.6a) changed slightly (<1 cm) at the system planter sites, GS, CS, and OS, and between 1 and 2 cm at the NS site, while the large average change for the SS site is attributable to an early loss of plants at this site (Fig.7d). Average change in plant heights (Fig.6b) for the system planters at GS, CS, and the non-system control, NS, were comparable; small average height change for SS was again a result of plant loss; and relatively small change in average height for OS was due to the storm damage described above. The high mortality at SS may have been due to rabbit predation.

Because of the openings around the plant material, there was minimal weed incursion that was easily removed. The sites GS, GN and SS were located in a large urban park and so were susceptible to animal interactions, such as raccoon, rabbits and squirrels falling into planters, eating plants or digging into planters. The GN and SS sites were in public areas and were subject to lawn mower damage, green house repairs, and park maintenance. No appreciable insect damage was noted at any of these sites. The CS site was located near a railroad yard and was subjected to pollution from that area. In addition, it was a recently reclaimed brownfield and so was open to prevailing winds and non-mitigated temperatures. This site was also surrounded by newly recovering native plants, such as stiff goldenrod. Insect activity was high, but the plants suffered little damage. The OS site was located on a 22nd floor patio in the downtown city area. It suffered storm damage to plants that appeared to be the result of placement near ornamental planters more than anything else. There were red spider mites at this site, but no insect damage to plants. Some of the planters had slugs, which again appeared to come from the ornamental planters. This also may have contributed to the mortality of *S.spectabile* and *S.scoparium* at this site. Appendix I, Figs.I-3a through I-3c, provide a comparison of the average maximum temperatures at GS, CS and OS showing the difference in heat effects across them. OS had the highest maximum reflecting the mid-city urban heat island effect, while GS had the lowest maximums during the season's heat peak suggesting an ameliorating effect of the green park surroundings as well as the surfaces on which the planters rested.

There was a significant difference in measurements across sites as shown by ANOVA for *S.spectabile* height and *S.scoparium* plug width and height (Appendix II, Tables II-1 through II-4). This may, among other things, be a reflection of the storm damage to these two species at the OS site, resulting in early mortality.

<u>Experiment 3</u>: *Do plant containers designed using the modified CIPS model allow plants to survive over a Chicago winter season?* HOBO data from the end of the growing season in 2006 to tear down in late May of 2007 shows that the containers with the modified CIPS system, GS, CS, and OS, did not provide appreciable insulation and show no more benefit in buffering winter temperatures than NS, the control planter without the system (Fig.8). (See Appendix III for details by site.)

At GS (Appendix III, Fig.III-1) during the period of minimum temperatures in early February, the soil temperature was measured at approximately 0C different from the surface temperature. However, as compared to the control non-system planter at the same location, there was less of a lag in planter warm up as surface temperatures rose. At CS (Appendix III, Fig.III-2) and OS (Appendix III, Fig III-3) during the same period of minimum temperatures, the soil temperature was also measured at approximately 0C different from the surface temperature and actually dropped below surface temperature until finally warming up. At GN, the control site with non-system planters, the soil temperature followed this same pattern (Appendix III, Fig.III-4). ANOVA analysis (Appendix II, Table II-5) shows, however, that there was a significant difference in surface and soil temperatures among both the CIPS systems themselves and the CIPS systems and non-system planters, suggesting site variables that affected winter temperatures.

The over winter mortality rates for all sites (Table 2) reflect winter stresses on survival. As compared to the SS site, in which planting was directly into the soil, plants in both modified CIPS and non-system planters showed a lower survival rate. The one species exception was *J.horizontalis*.

Experiment 4: *Within a variety of urban settings, do selected plant species survive a Chicago winter season in the modified CIPS systems?* Over winter mortality for the study is defined as lack of bud-break at the close of the testing period and further confirmed by condition of roots and plant desiccation. Comparison between number of survivors at the end of the growing season and at test tear downs after the winter season was used to judge success of given plant species in the modified CIPS systems (Table 2). Mortality rates show that species in soil (SS) over winter better than those in the modified CIPS containers (GS, CS, OS) as well as the non-system planters (NS). The exception was *J.horizontalis*, which had a high survival rate at all sites; only one plant was lost overall. *R.copallina* showed the lowest over winter survival rates in the modified CIPS systems (GS, CS, OS) while all plants in soil (SS) and 50% of the plants in the non-system planters (NS) survived. High mortality of *S.scoparium* at the OS site was anticipated after the storm damage incurred during the growing season. ANOVA results for species across all sites show that only for *S.scoparium* is survival difference significant (Appendix II, Table II-6). For the modified-CIPS sites, there was no statistical difference in death rates (Appendix II, Table II-7).

Conclusions

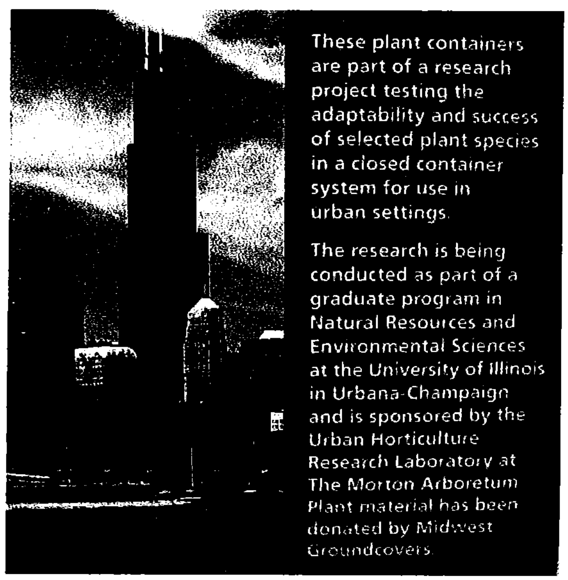
The planters, as designed for this experiment, were successful as a low maintenance greening system for urban residents. Plant material had high survival rates through the growing season, and the planter systems themselves required no additional watering after initial setup. Plant growth and mortality over the growing season varied, but with few exceptions all of the species did well. While most species, apart from *R.copallina*, survived through the winter season in the planters, the control site in which plants were directly in soil had the highest over winter rates of survival. Surface and soil temperature comparisons through the winter season show that this design provided little insulating effect.

Two recommendations for design modification are suggested by this study. First, insulation or a change of the container material from plastic should be considered to enhance winter survival rates in climates comparable to that for the study sites. Second, to avoid polluting runoff through the drains with contaminants in the structural mix and fertilizer, a modification of the design to funnel rainwater directly into the reservoirs should be considered. To make the second modification feasible, however, there would be a related need to develop plant replacement packages in which the plants are sealed in; this is beyond what the average user would be expected to do.

Finally, in addition to a design change, if plants are intended to survive over winter, the species used in the system should be evaluated for root-killing temperature ranges and appropriate species selected.

Acknowledgements

This study was conducted through the help and support of many individuals and organizations in the Chicago area. Morton Arboretum's Urban Horticultural lab under Abbas Shirazi is responsible for the initial concept of the planters, and its volunteers and staff provided invaluable support and help in planter construction and delivery. Midwest Groundcovers, through Grace Koehler, kindly donated all of the plant material used in the study. Stacy Monroe of the Department of General Services of the City of Chicago helped find sites in Chicago. Rand Ekman of OWP/P Architects was kind enough to offer the company's 22nd floor patio as one of the study sites. Bryce Bandstra and Ellen Sargent of the Chicago Park District were also instrumental in site location. Stephen Bell, Director of the Chicago Center of Green Technology, offered use of an area at his location. I am grateful for the support and encouragement that individuals at all of these locations provided through the year-long research effort. In addition to those noted above, I would like to give special thanks to Beverly Fields at OWP/P and Miguel DeValle and Thomas Constanza at Garfield Park Conservatory. Finally, I wish to thank Dr. Jeff Masters, Chief Meteorologist of The Weather Underground, Inc., for giving me permission to use Personal Weather Station data, and Rick Bolinger, Environmental Scientist, at MWH Americas, Inc. for sharing weather data collected at the Chicago Center for Green Technology site.



Tables and Figures

Diag.1 Schematic diagram of modified CIPS containers.

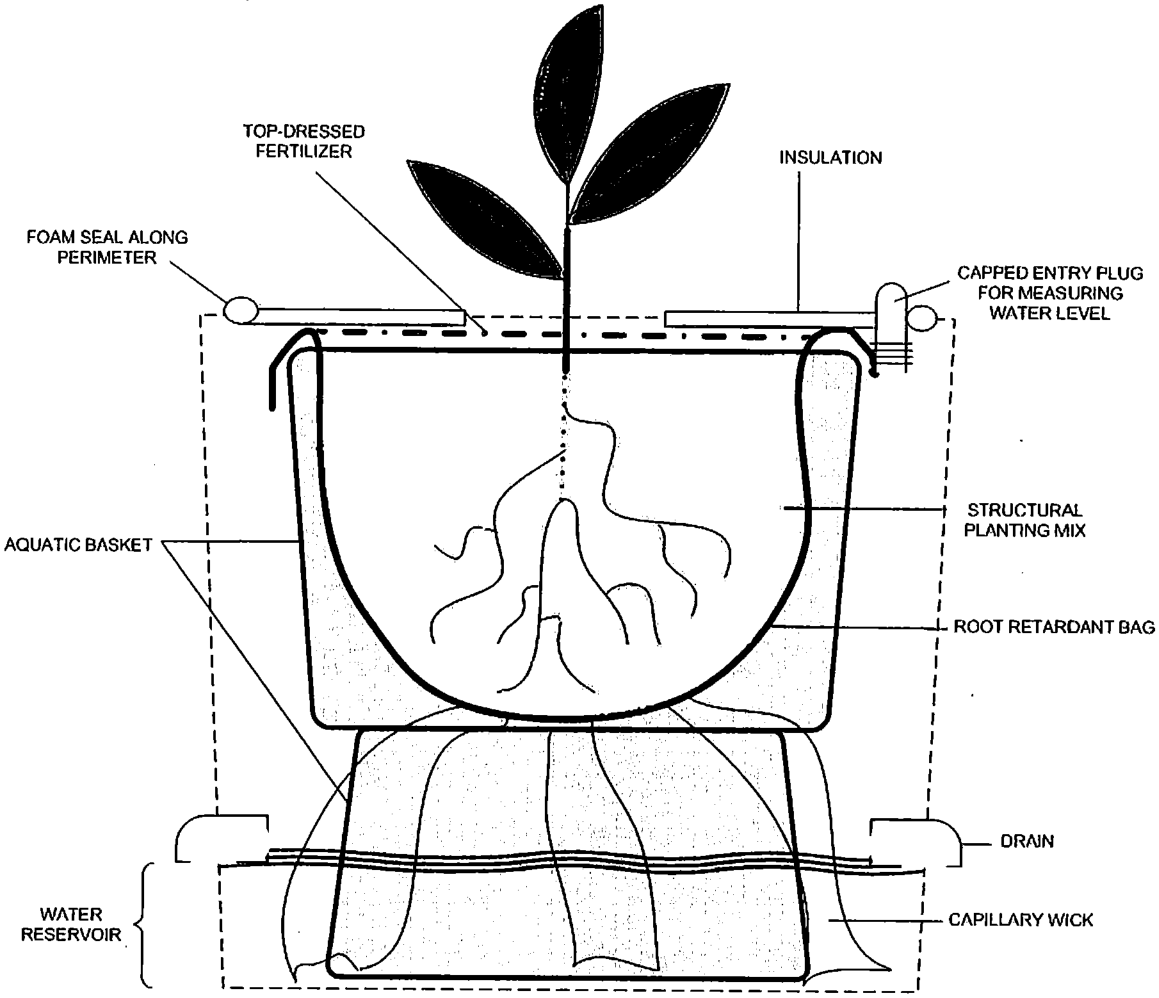


Fig.1 Mean water levels (cm) of all reservoirs during the growing season (2006) compared to average temperatures(C) and rainfall (cm) for weather station data collected at two sites.

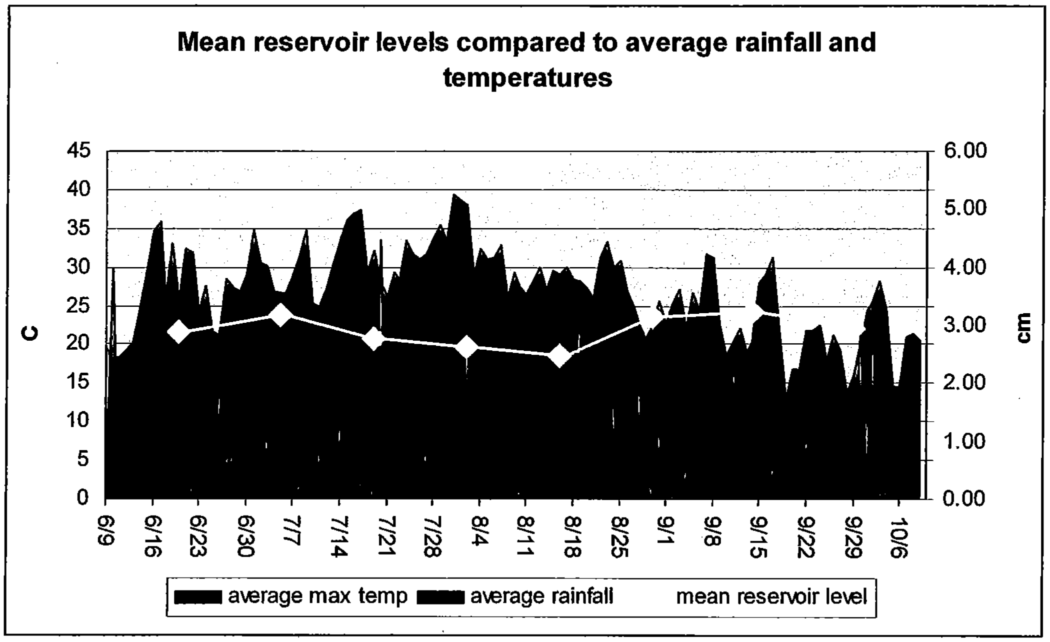
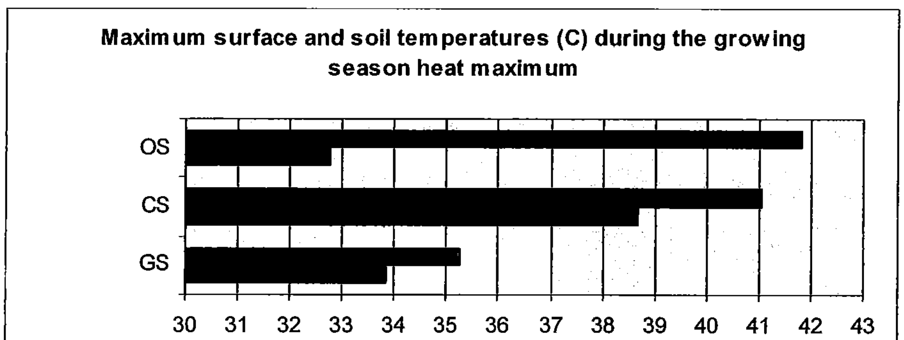


Fig.2 Maximum surface and soil temps at sites for growing season (2006) during maximum heat period (7/19 to 8/2) showing insulating effect of soil/containers in system planters.



	GS	CS	OS
max surface	35.25	41.05	41.81
max soil	33.85	38.66	32.78

Fig.3a *R.copallina* average change in twig elongation over growing season (2006).

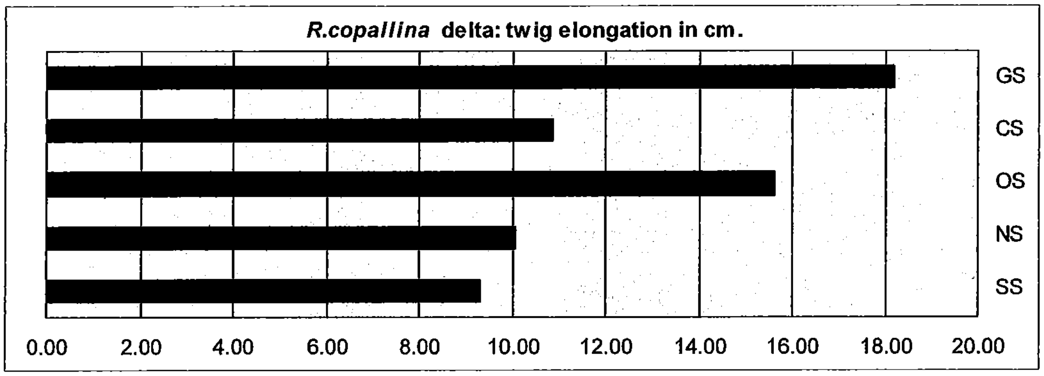


Fig.3b *R.copallina* average change in stem diameter over growing season (2006).

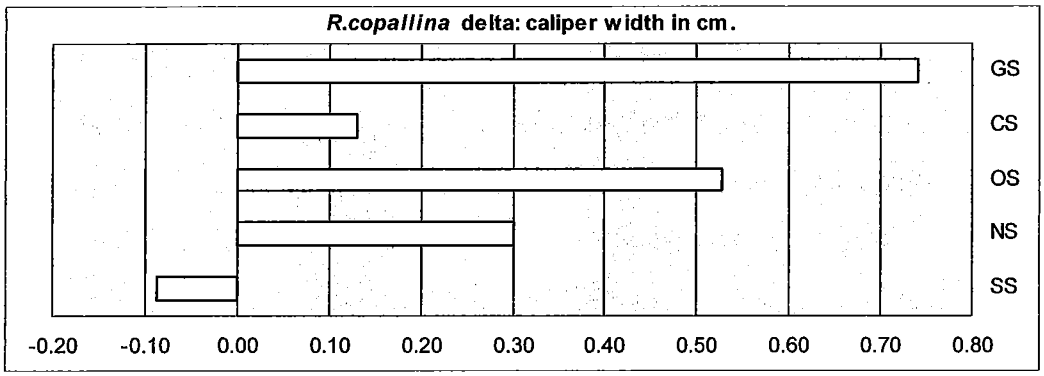


Fig.4a *J.horizontalis* average change in maximum spread over growing season (2006).

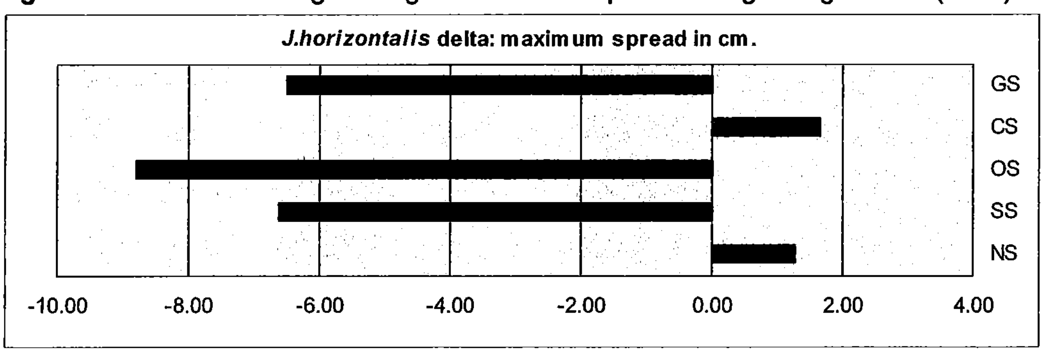


Fig.5a *S.spectabile* average change in number of stems over growing season (2006).

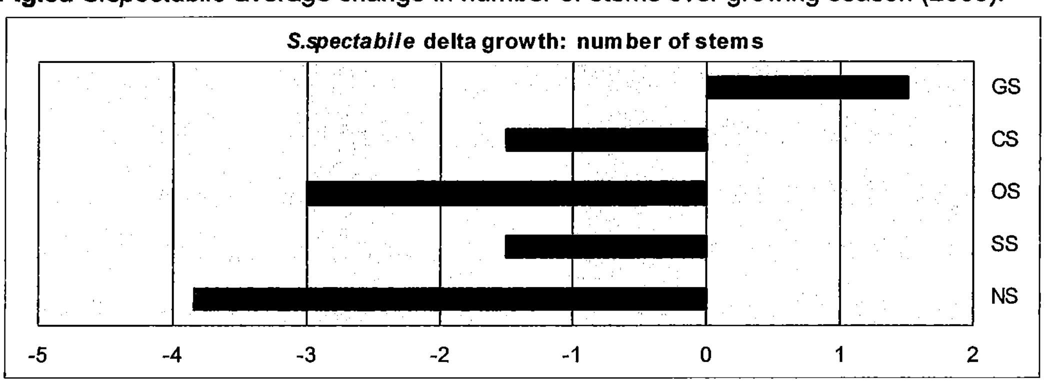


Fig.5b *S.spectabile* average change in plant height over growing season (2006).

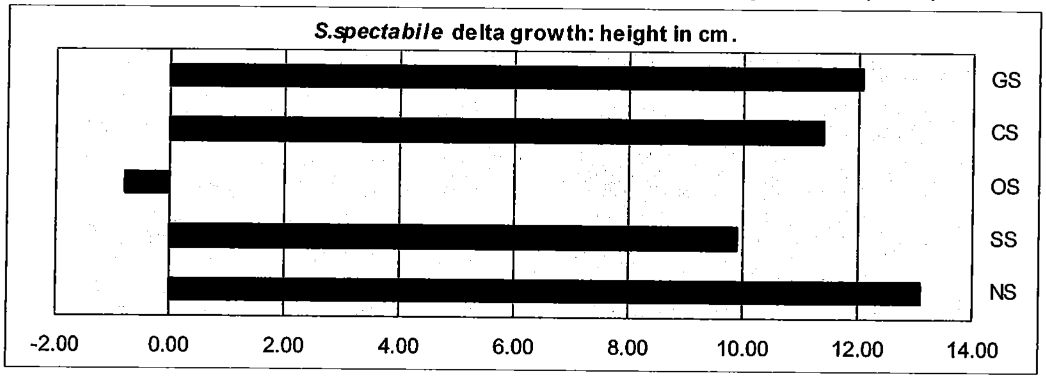


Fig.6a *S.scoparium* average change in plug diameter over growing season (2006).

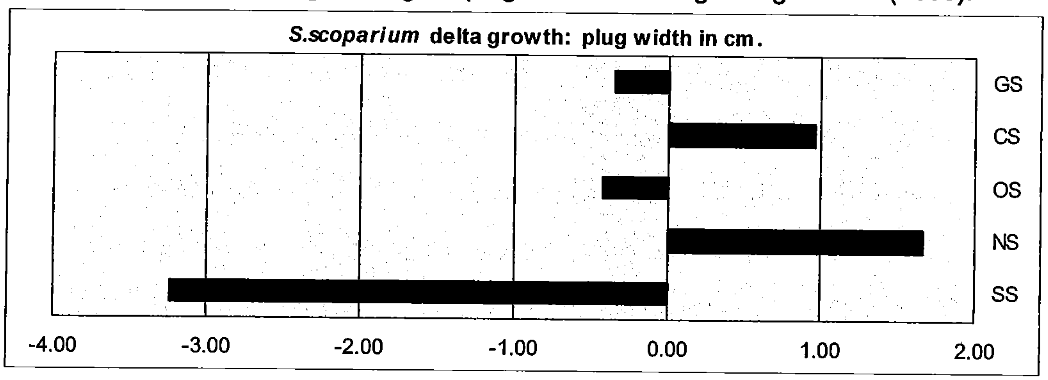


Fig.6b *S.scoparium* average change in plant height over growing season (2006).

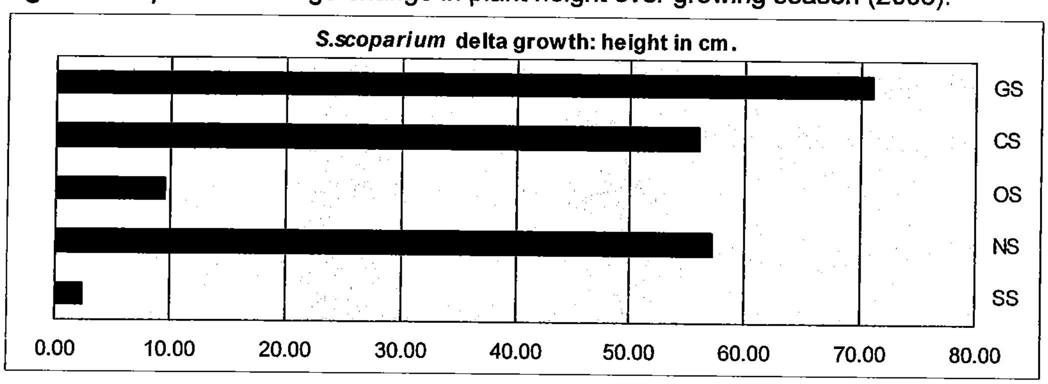


Fig.7a: Mortality totals for *R.copallina* through entire test. Final measurements were completed in May 2007.

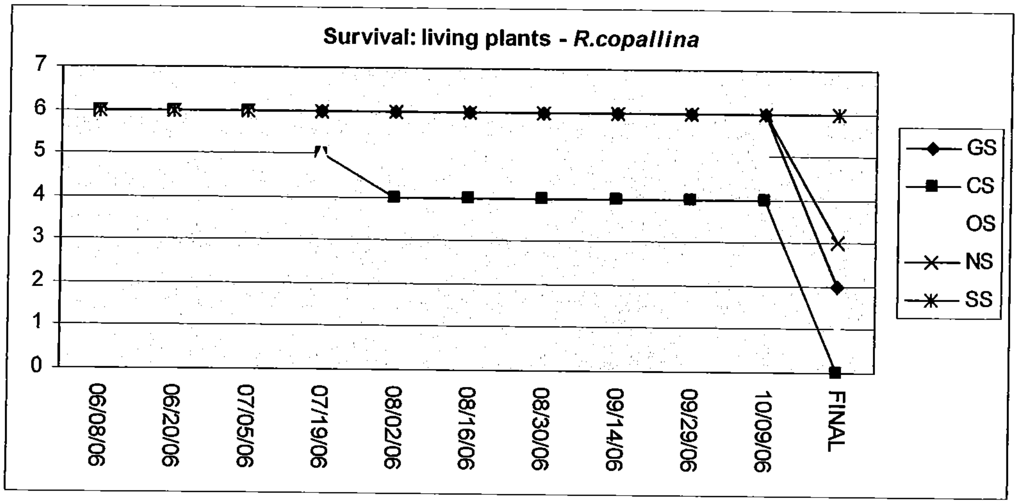


Fig.7b Mortality totals for *J.horizontalis* through entire test. Final measurements were completed in May 2007.

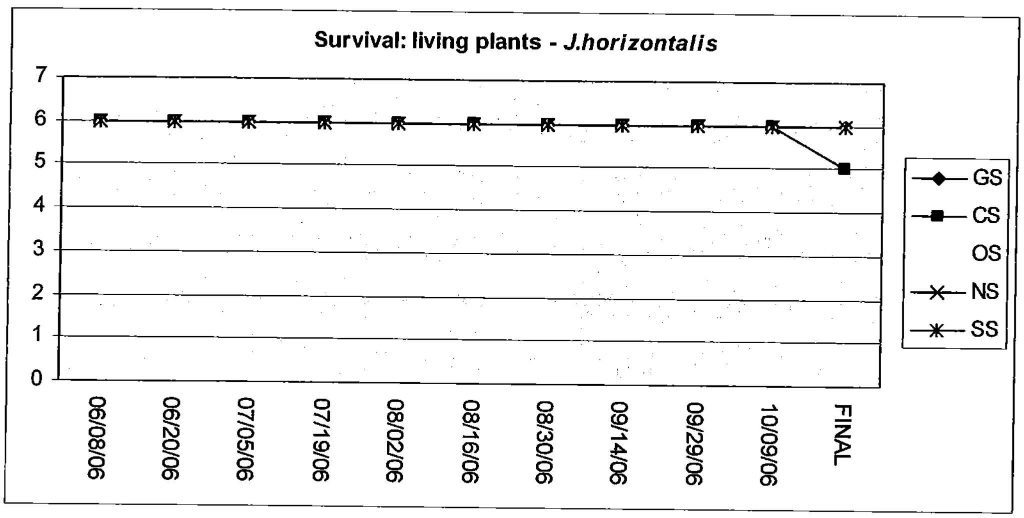


Fig.7c Mortality totals for *S.spectabile* through entire test. Final measurements were completed in May 2007.

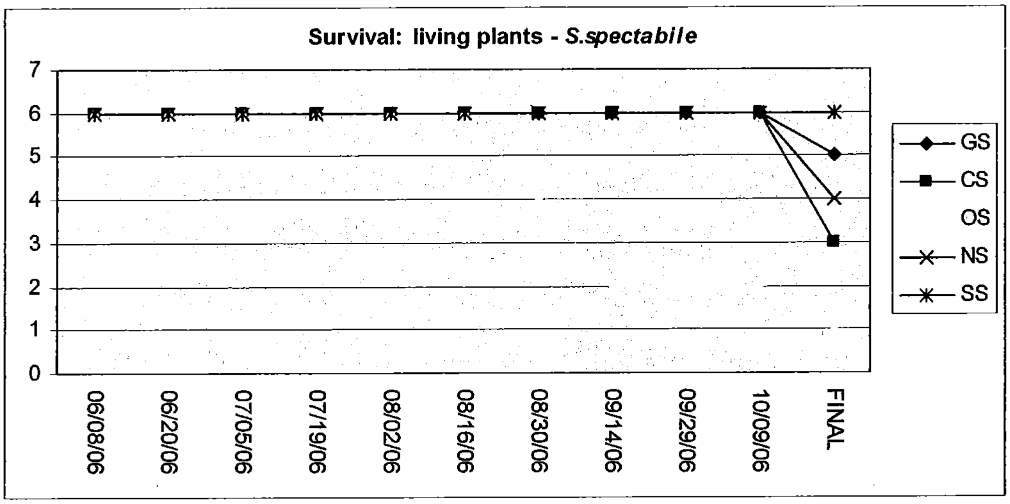


Fig.7d Mortality totals for *S.scoparium* through entire test. Final measurements were completed in May 2007.

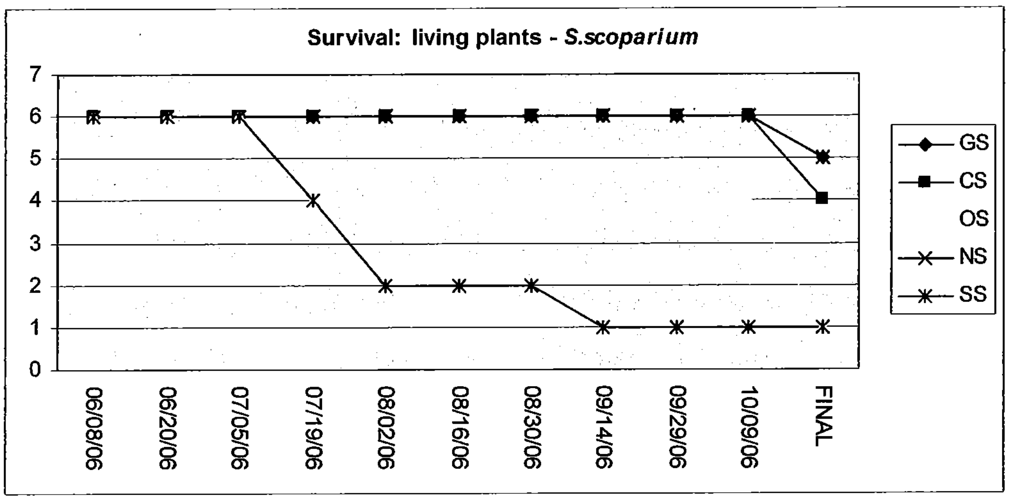
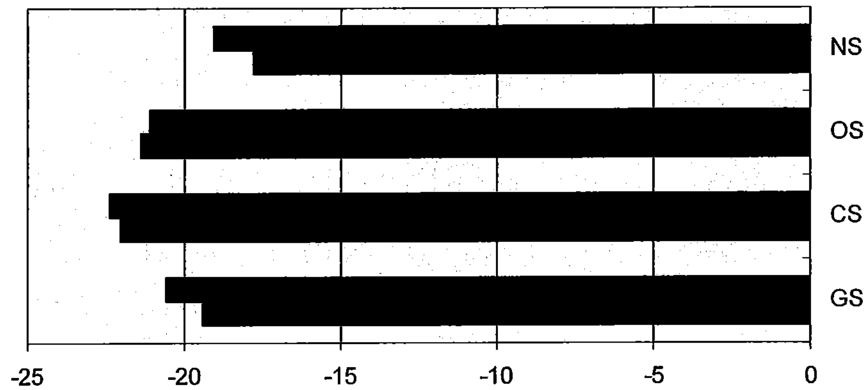


Fig.8 Minimum surface and soil temperatures at sites for over winter period 10/09/2006 through 5/22/2007 showing lack of insulating effect of soil/containers in system planters.

Minimum surface and soil temperatures (C) through over winter period



	GS	CS	OS	NS
■ min soil	-20.57	-22.35	-21.1	-19.08
■ min surface	-19.4	-22.04	-21.4	-17.75

Table 1 Reservoirs through growing season for *R.copallina* at CS site. Shaded areas represent times in which plants were dead. Note lack of capillary draw in these periods.

Water levels for R.coppalina through growing season										
	6/8	**6/20**	**7/5**	**7/19**	**8/2**	**8/16**	**8/30**	**9/14**	**9/29**	**10/9**
CS-D1	15.88	11.43	12.70	11.43	6.35	7.62	12.70	13.97	11.43	11.43
CS-D2	15.88	11.43	12.70	8.89	8.89	8.89	13.97	13.97	11.43	11.43
CS-D3	15.88	13.97	12.70	13.97	13.97	13.97	13.97	15.24	13.97	13.97
CS-D4	15.88	11.43	13.97	8.89	6.35	6.35	11.43	11.43	7.62	12.70
CS-D5	15.88	11.43	13.97	13.97	13.97	13.97	13.97	13.97	13.97	13.97
CS-D6	15.88	11.43	13.97	11.43	8.89	6.35	8.89	11.43	8.89	11.43

Table 2 Over winter survival showing number of plants that lived through the winter as a percentage of plants alive after the growing season.

	R.copallina		***J.horizontalis***		***S.spectabile***		***S.scoparium***	
Site	Plants surviving	Survival rates	Plants surviving	Survival rates	Plants surviving	Survival rates	Plants surviving	Survival rates
GS	2 of 6	33%	6 of 6	100%	5 of 6	83%	5 of 6	83%
CS	0 of 4	0%	5 of 6	83%	3 of 6	50%	4 of 6	67%
OS	1 of 5	20%	6 of 6	100%	1 of 2	50%	1 of 4	25%
NS	3 of 6	50%	6 of 6	100%	4 of 6	67%	5 of 6	83%
SS	6 of 6	100%	6 of 6	100%	6 of 6	100%	1 of 1	100%

Appendix I: detail reservoir water levels, ambient temperatures and rainfall, and surface/soil comparisons

Fig.I-1a Site GS average system water levels over growing season (2006).

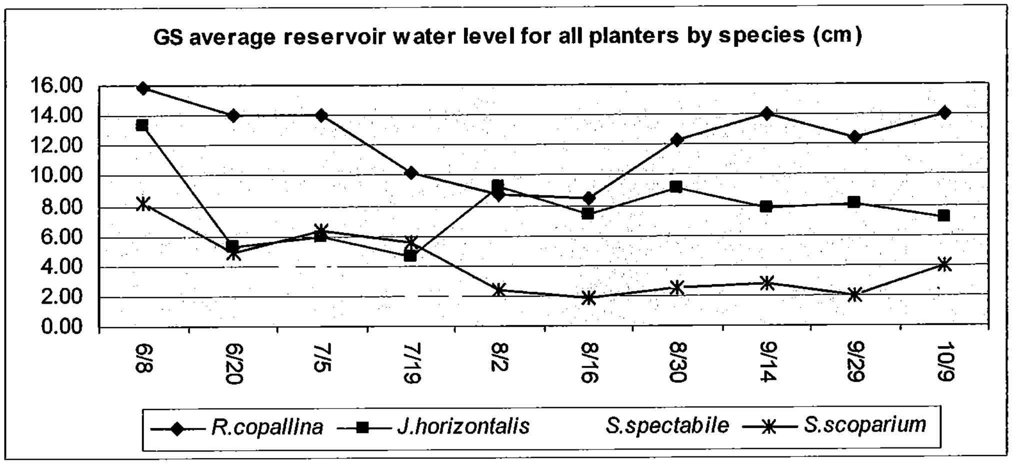


Fig.I-1b Site CS average system water levels over growing season (2006).

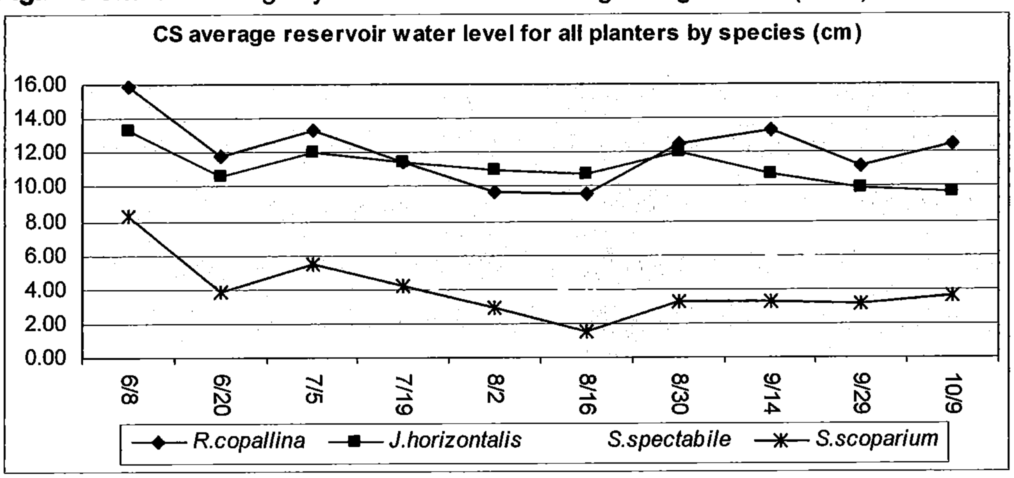


Fig.I-1c Site OS average system water levels over growing season (2006).

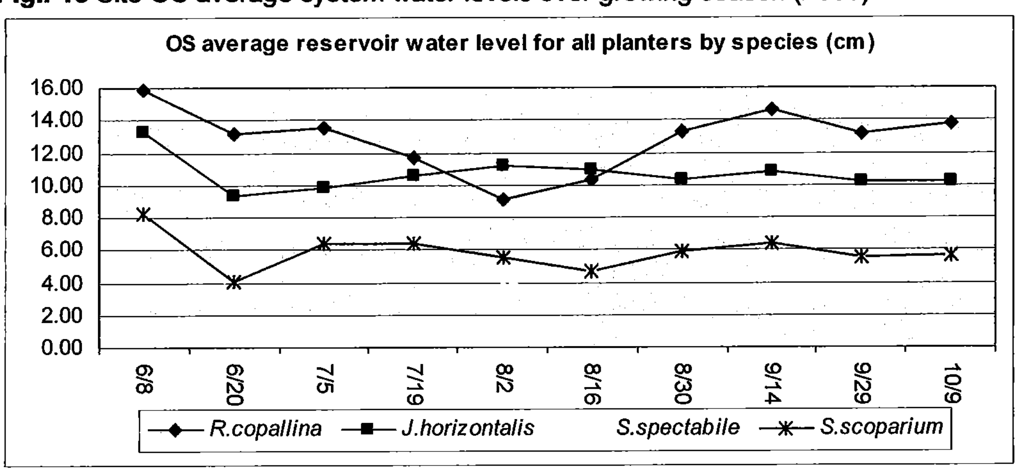


Fig.I-2a Maximum and minimum temperatures as tracked at two weather stations near test sites through growing season (2006).

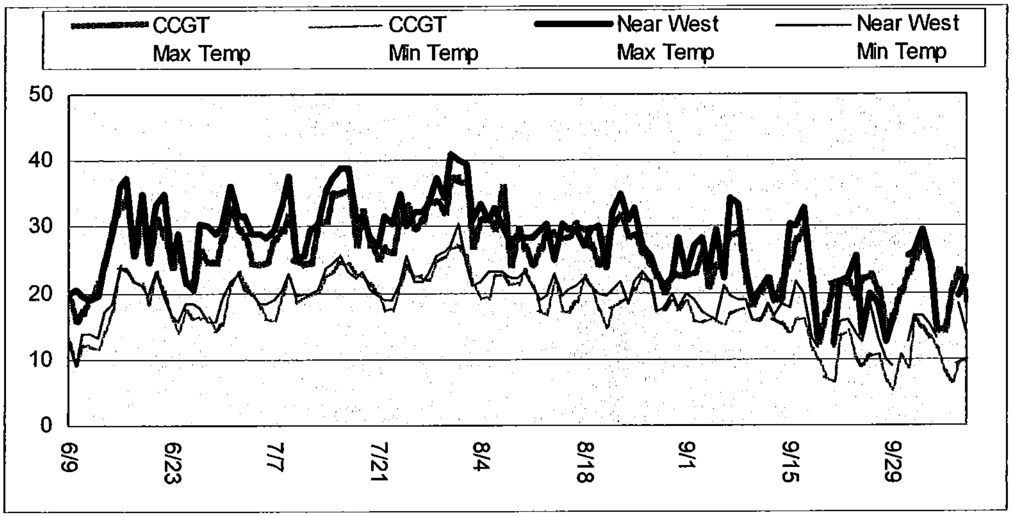


Fig.I-2b Rainfall measurements as tracked at two weather stations near test sites through growing season (2006).

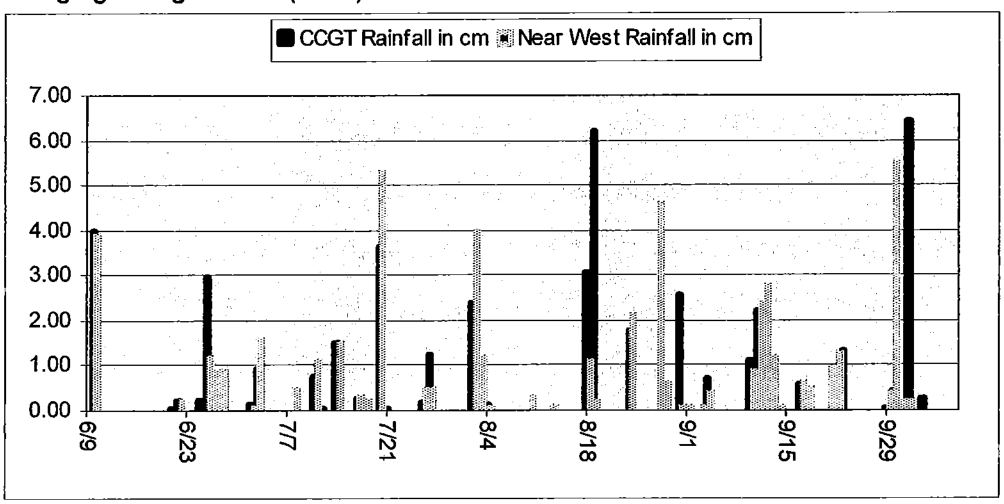


Fig.I-3a Surface vs. soil maximum temperatures during peak heat period at GS site

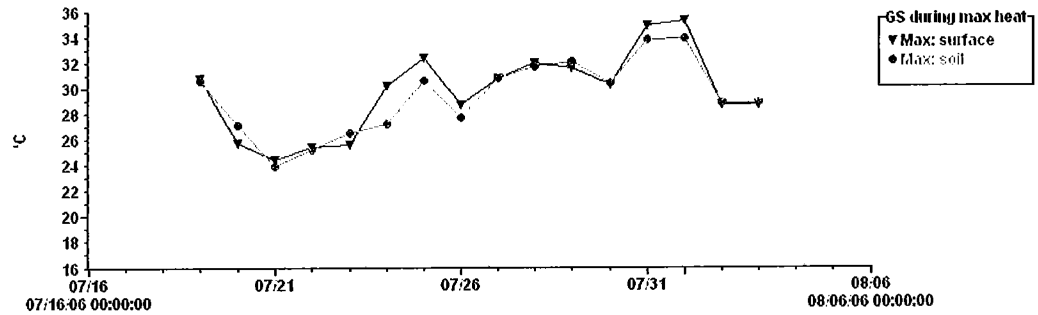


Fig.I-3b Surface vs. soil maximum temperatures during peak heat period at CS site

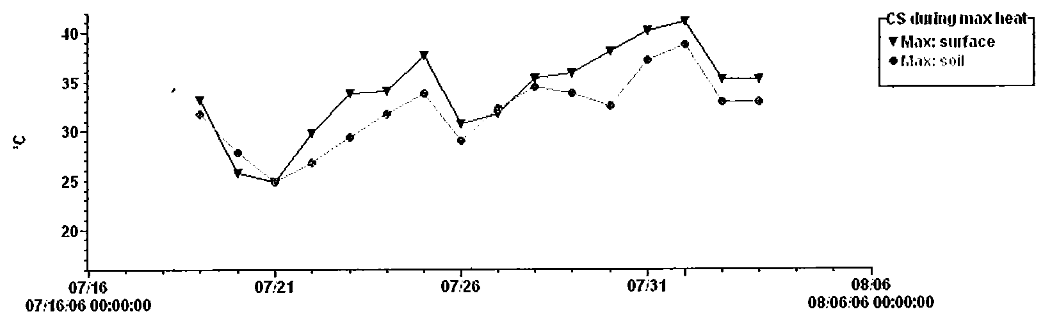
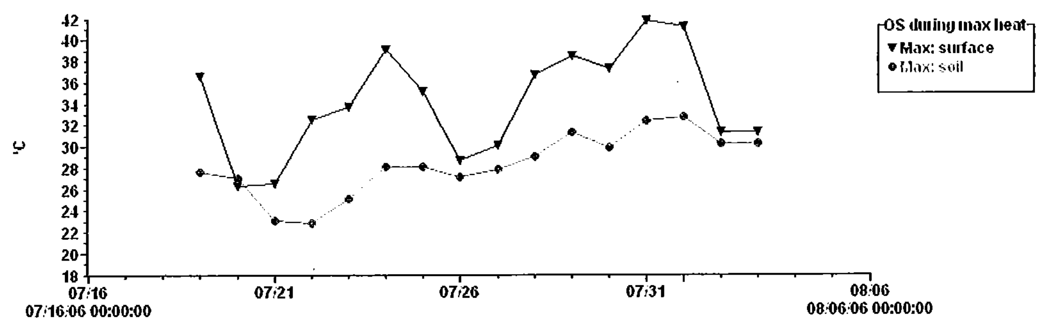


Fig.I-3c Surface vs. soil maximum temperatures during peak heat period at OS site



Appendix II: ANOVA analyses

Table II-1 ANOVA for *R.copallina* growing season changes

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
twig elongation	363.51875	4	90.87969	0.924612	0.46538458	2.758711
caliper width	2.5308848	4	0.632721	2.263289	0.09079996	2.758711

Table II-2 ANOVA for *J.horizontalis* growing season changes

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
maximum spread	572.42493	4	143.1062	1.583651	0.20958144	2.758711

Table II-3 ANOVA for *S.spectabile* growing season changes

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
number of stems	112.53333	4	28.13333	2.598522	0.06053564	2.758711
height	769.46261	4	192.3657	3.052916	0.03535983	2.758711

Table II-4 ANOVA for *S.scoparium* growing season changes

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
plug width	84.580513	4	21.14513	10.88246	2.9998E-05	2.758711
height	23073.926	4	5768.481	12.68074	9.0321E-06	2.758711

Table II-5 ANOVA for temperature difference between surface and soil measurements over winter (computed as soil temperature minus surface temperature)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
modified CIPS GS,CS,OS	407.4821	2	203.7411	31.56784	7.88E-14	3.009127
including NS	1384.805	3	461.6018	83.16681	1.79E-47	2.61484

Table II-6 ANOVA between survivors at end of growing season and after over winter for all sites

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
R.copallina	18.4	4	4.6	0.807018	0.570194	5.192163
J.horizontalis	0.4	4	0.1	1	0.485657	5.192163
S.spectabile	25	4	6.25	4.166667	0.07478	5.192163
S.scoparium	33.4	4	8.35	5.566667	0.043797	5.192163

Table II-7 ANOVA between survivors at end of growing season and after over winter for modified-CIPS sites

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
R.copallina	4	2	2	0.25	0.79356	9.552082
J.horizontalis	0.333333	2	0.166667	1	0.464758	9.552082
S.spectabile	17.33333	2	8.666667	4.727273	0.11822	9.552082
S.scoparium	10.33333	2	5.166667	2.214286	0.25664	9.552082

Appendix III: Minimum surfaces temperatures compared to difference in degrees (C) between surface and soil sensor measurements.

Fig.III-1 GS: minimum surface temperature over winter compared to number of degrees different in soil as measured by data sensors.

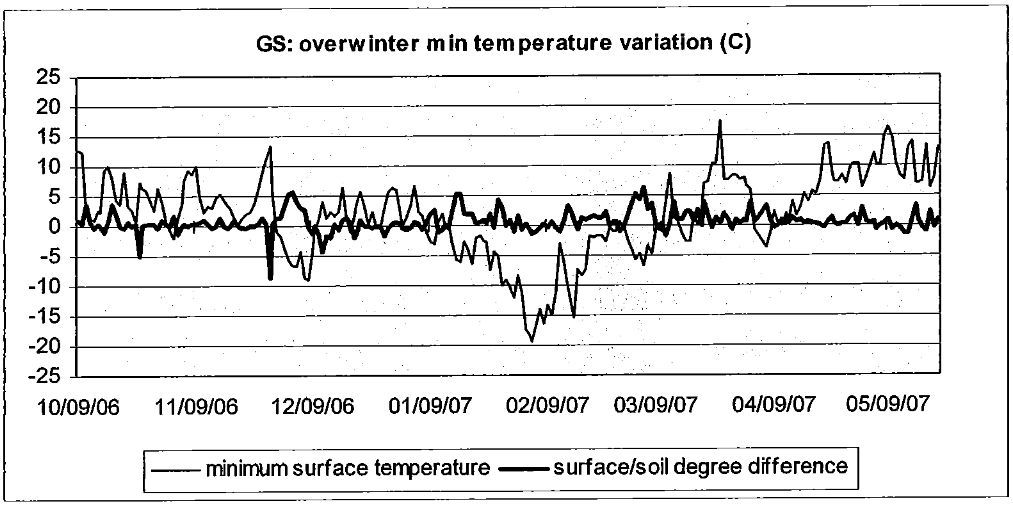


Fig.III-2 CS: minimum surface temperature over winter compared to number of degrees different in soil as measured by data sensors.

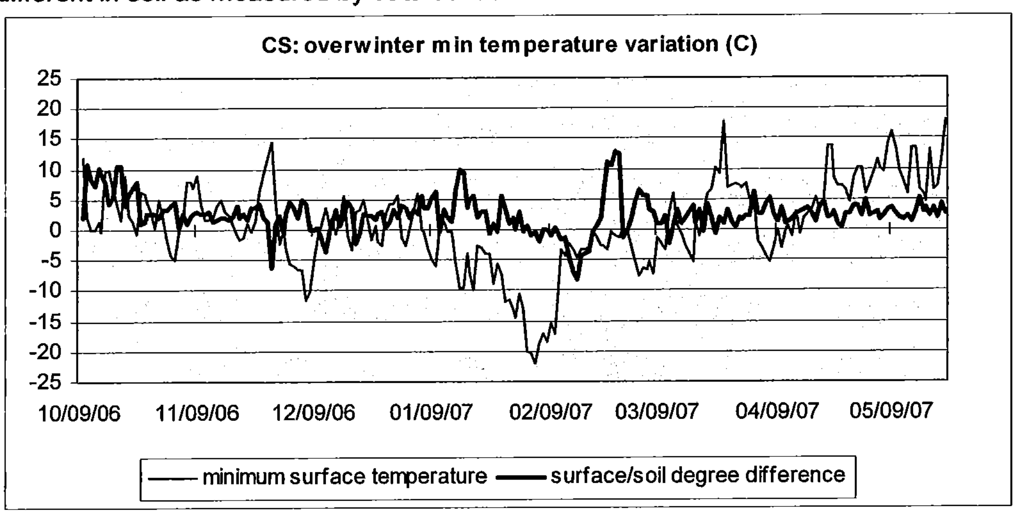


Fig.III-3 OS: minimum surface temperature over winter compared to number of degrees different in soil as measured by data sensors.

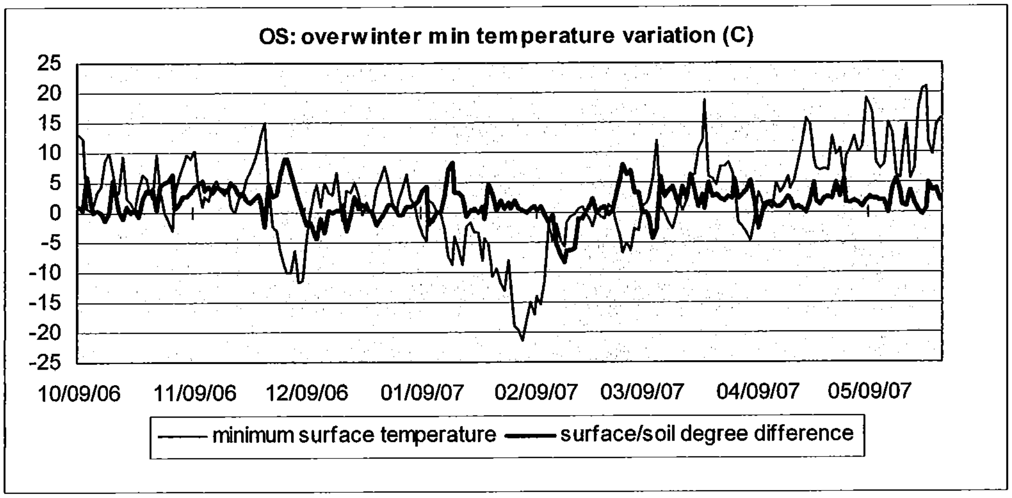
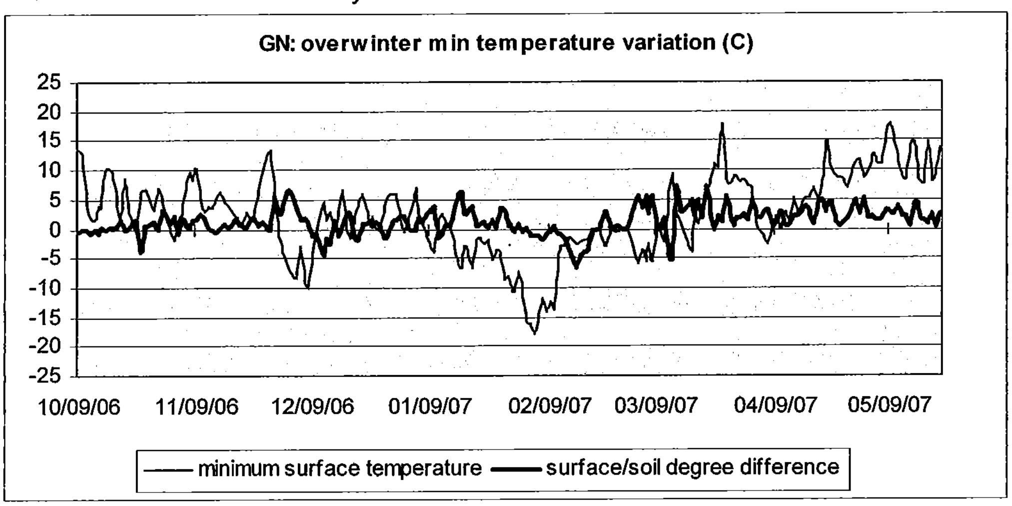


Fig.III-4 GN: minimum surface temperature over winter compared to number of degrees different in soil as measured by data sensors.



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