Urban Greening: A Case Study to Determine the Efficacy of Using Low Maintenance Planters as a Means of Growing Plants in Chicago Urban Settings[1]

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Abstract

This paper describes an experiment designed to test a planter system that can be used by urban residents in greening rooftops, balconies and patios. Design emphasis 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, requiring no additional watering after setup through the growing season. Plant growth and mortality over the summer varied, as did over winter survival. Plant survival rates through the end of the growing season in the planter systems were 83% for *Rhus copallina*, 100% for *Juniperus horizontalis*, 78% for *Sedum spectabile*, and 89% for *Schyzachyrium scoparium*. All species lived through the winter season in the system planters. *R. copallina* had the highest mortality rate with 80% of plants alive at the end of the growing season not surviving the winter. The control site with plants directly in soil had the highest over winter rates of survival; all plants alive at the end of the growing season survived through the winter. Surface and soil temperature comparisons through the winter season show that this design provided little insulating effect.

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.

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 (10, 15–17, 28–30) and potential adaptability to container planting (14). City plants are subject to a wide variety of conditions that challenge their survival including temperature and water extremes, pollution and disease. At the same time they play an integral role in securing the many benefits of environmentally friendly urban designs (26); 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 (26). 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 (22). 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 (25). The advantages of urban ‘greening’ are well documented. Vegetation can filter

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airborne pollutants, provide sound buffering, and reduce rainfall runoff; plants contribute to carbon sequestration (18); and urban trees remove significant amounts of contaminants through in-leaf usage and interception (21). Economically, 'heat-island' effects caused by reflections off buildings and streets are ameliorated, resulting in energy and monetary savings due to reductions in heating and air conditioning expense (19). While social and aesthetic effects may be more difficult to quantify, studies in such diverse areas as improved surgical recovery rates and reduced costs of anti-social behavior have been conducted (23, 27). Difficult to quantify, but not insignificant is the concept that exposing people to beauty fosters an appreciation of beauty (23).

The urban landscape is a complex ecosystem that includes the effects of humans (1, 2). 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…' (4) which define it. In addition to the traditional image of cities as economic hubs, they are global ecological driving forces (9). 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.

While the concept of closed capture container systems as a means of controlling water use, nutrient availability and runoff has been the subject of a number studies (3, 11, 12), the primary focus has been on nursery applications (5, 8, 24) and green roofs (7, 13, 31). Although there has been some examination of container systems for home gardeners (6, 20), more research needs to be done on the use of closed system containers at actual city locations. This study was conducted at sites within the 'heat-island' of Chicago, specifically to test plant survival and growth in low-maintenance plant containers and of selected species in a realistic urban setting.

We hypothesized that our modified container system would moderate container temperature and moisture extremes and that selected plant species in the containers would survive differently according to ambient temperature and precipitation values, container system parameters and various planter environments/locations within the urban landscape. Specific questions include:

1. *Do plant containers constructed using the modified CIPS model provide a viable option in general for growing selected plants in Chicago urban settings over a growing season?*
2. *Do selected plant species survive and grow using the modified CIPS planter system at various urban locations in Chicago over a growing season?*
3. *Do plants in general survive over a Chicago winter season in containers designed using the modified CIPS model and how does survival correlate with temperature?*
4. *Do selected plant species survive a Chicago winter season in the modified CIPS systems at each location?*

Materials and Methods

CIPS technique. The closed insulated pallet system (CIPS) as originally designed by Oregon State University (12) 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 less water and fertilizer (11). In a comparison study of tomato cultivars in CIPS and an open container system using different water qualities, growth and yield were greater using CIPS in both cases studied (3).

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 insulating foam sealant and were then covered with burlap; 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 (Fig. 1).

Test sites. The planters were installed at three locations. Sites 1–3 (hereafter, GS, NS, SS) were set up on Garfield Park Conservatory grounds, 300 N. Central Park Avenue, Chicago.

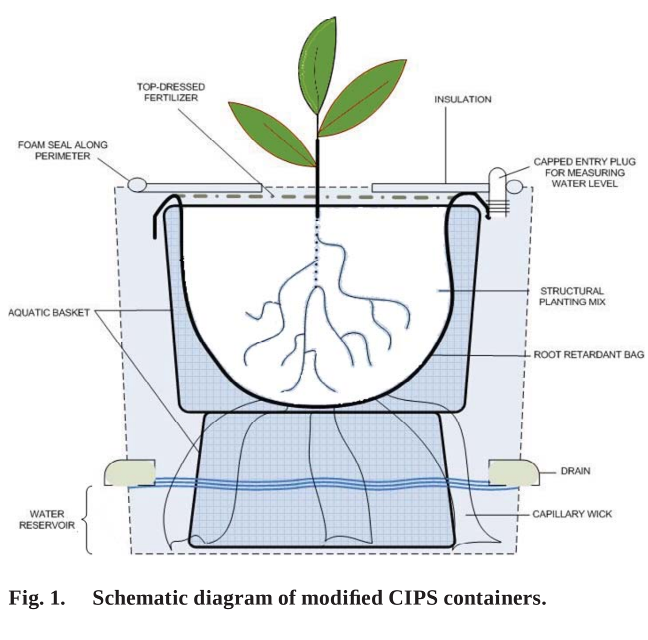


Fig. 1. Schematic diagram of modified CIPS containers.

These are ground level sites adjacent to greenhouses and surrounded by park environment. The planters were placed on a surface of crushed light-colored stone. Site GS was protected by its position between greenhouses resulting in early morning and late afternoon shade. All sites were open to wildlife, including rabbits, raccoons and squirrels. Sites NS and SS were watered as part of normal park maintenance. Site GS watering was controlled as part of the experiment. Site 4 (hereafter, CS) was at the Chicago Center for Green Technology (hereafter, CCGT), 445 North Sacramento Blvd., Chicago. This is a ground level site on a mulched surface, simulating a patio or street-side environment. It receives late afternoon shade from a building to the west. Located on a recovered brownfield next to a railroad yard, it is subject to industrial pollution. Site 5 (hereafter, OS) was at OWP/P, an architecture firm, at 111 W. Washington Street, Chicago, within the 'Chicago Loop'. It is located on a patio on the 22nd floor of a building with exposure on the 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 the south and east, which is typical of a city location. Buildings on the north, east and west are across streets. The site is open to northerly winds. Each site had 6 replications of each of the test species. At Site NS, plants were placed into planters without the special planter system. At Site SS, plants were placed directly into the ground. At Sites GS, CS, and OS plants were in planters with the modified CIPS system.

Planter construction materials. Plant materials were placed in three sizes of plastic planters: small square [32 × 27 × 27 cm (12.5 × 10.8 × 10.8 in)], medium square [51 × 51 × 45 cm (20 × 20 × 17.6 in)], and large round [61 × 51 × 51 cm (24 × 20 × 20 in)] containers. Black, mesh-type hard plastic aquatic baskets were used for pouch framework and support. For the pouch framework three sizes were used: small [23 × 23 × 13 cm (9 × 9 × 5 in)], medium [28 × 28 × 18 cm (11 × 11 × 7 in)], and large [36 × 36 × 25 cm (14 × 14 × 10 in)]. For support of the pouch framework two sizes were used: small [10 × 10 × 10 cm (4 × 4 × 4 in)] and medium/large [28 × 28 × 18 cm (11 × 11 × 7 in)]. Plants were placed in root retardant bags with tough bottoms in the following sizes: small [25 cm (10 in) diameter], medium [36 cm (14 in) diameter], and large [46 cm (18 in) diameter]. Wicking material made of 0.6 cm (0.25 in) batting was used to draw water. Two strips were cut for each container. For small bags, the wicks were 8 × 43 cm (3 × 17 in); for medium bags, wicks were 8 × 71 cm (3 × 28 in), and for large bags, 8 × 76 cm (3 × 30 in). Drains were made using 1.3 cm (0.5 in) 90 degree copper elbows. Plugs were constructed from PVC 'male adapters' and caps (small: 1.3 cm (0.5 in), medium: 2.5 cm (1 in), and large: 3.1 cm (1.3 in). FOAMULAR Insulation from Owens Corning [2.5 cm (1 in) thickness] was used for lids. GREAT STUFF 16 oz. Gaps and Cracks Insulating Foam Sealant (Home Depot) was used to seal around the insulation.

Planting materials. Thirty each of the following species were supplied by Midwest Groundcovers, LLC. St. Charles, IL: *Rhus copallina* L. 'Prairie Flame' #5, SC 20179.5G; *Juniperus horizontalis* Moench 'Blue Rug' #5, SC 20591; *Sedum spectabile* Boreau 'Autumn Joy' #1, SC 20243.1G; and *Schizachyrium scoparium* #1, SC 20407.1G. All plant material was container grown. A structural planting mix was made up of Sunshine peat moss, Therm-o-Rock #3A vermiculite, FarmGro plant food 0-46-0 (super triple phosphate), ECOpHRST™ pulverized dolomitic limestone, and Sof'n-Soil coarse lawn and garden gypsum. To each 10 gal 50/50 mixture of peat and vermiculite, 114 g (4 oz) of Dolomite, 68 g (2.4 oz) of Gypsum, and 37 g (1.3 oz) of Triple phosphate were added. Osmocote® classic 14-14-14 slow release fertilizer was added as top-dressing during planter construction.

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

Planter construction. Two holes were drilled on opposite sides of each planter at water reservoir height levels: small planter at 8.3 cm (3.3 in), medium planter at 13.3 cm (5.3 in) and large planter at 15.9 cm (6.3 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 × 9 cm (3.5 × 3.5 in), medium planter approximately 28 × 28 cm (11 × 11 in) to accommodate the juniper spread, and large planter approximately 11 × 11 cm (4.5 × 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. 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 insulating foam sealant 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 5.18 gm (0.18 oz), medium containers 9.8 gm (0.35 oz), large containers 34.5 gm (1.22 oz). 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 Fig.1). HOBO data loggers were set up at one *J. horizontalis* planter at each of four sites: GS, CS, OS and NS. 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 in the planter. The external sensor probes were inserted at 6–10 cm (2.4–3.9 in) depths at approximately 28 cm (11 in) from the planter edge.

Experiment questions and measurements. This study looked at four questions related to planter efficiency and plant survival in urban settings. First, '*Do plant containers constructed using the modified CIPS model provide a viable option in general for growing selected plants in Chicago urban settings over a growing season?*'. To determine the feasibility of the reservoir container system measurements of 1) planter system reservoirs levels, 2) temperature and rainfall data, and 3) surface and soil temperatures were taken. 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 temperature was downloaded at the time of water level measurements. The second question was '*Do selected plant species survive and grow using the modified CIPS planter system at various urban locations in Chicago over a growing season?*'. 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 clump 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. The third question was '*Do plants in general survive over a Chicago winter season in containers designed using the modified CIPS model and how does survival correlate with temperature?*'. All sites were visited monthly beginning October 25 through May 29 of the following year. At the first visit in October, reservoirs were refilled and some minor repairs, such as taping holes caused by site maintenance crews and re-attaching burlap, were done on planters and some light trimming was done on *J. horizontalis.* After this, planters and plant materials were no longer maintained, as would be expected of the level of care by urban residents in the winter season. HOBO sensor data giving surface and soil temperature was downloaded at each visit. The state of sites and planters was recorded, as well as conditions of plant material. Over winter success was determined by plant survival and temperature measurements to determine the insulating effects of the containers as designed. Minimum surface and soil temperatures at sites for the over winter period October 9, 2006, through May 22, 2007, were tabulated to measure potential ameliorating effects of the planters to surface temperatures. The final question was '*Do selected plant species survive a Chicago winter season in the modified CIPS systems at each location?*'. Plant condition over the period considered for 'winter season' analysis, late October of 2006 to late May 2007, was recorded to be used in final survival evaluation. Species' overwintering success was measured by comparing the number of plants and percentage of the original treatment alive after the growing season and after over wintering.

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.

Do plant containers constructed using the modified CIPS model provide a viable option in general for growing selected plants in Chicago urban settings over a 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 at CS and six planters 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. 2).

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. 3).

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, two plants died early in the growing season (Table 2) and from that point on, water reservoirs showed no drop in levels for these plants.

Do selected plant species survive and grow using the modified CIPS planter system at various urban locations

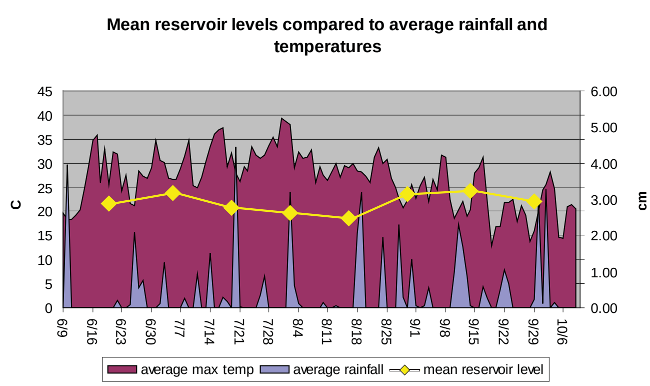


Fig. 2. Mean water levels (cm) of all reservoirs during the growing season (2006) compared to average temperatures (C) and rainfall (cm) for weather station data collected at two sites. Ambient temperatures reached as high as 40C (104F) in early August. Rainfall occurred at regular intervals during the growing season, with a maximum rainfall of approximately 4.5 cm (1.8 in) during a storm in late July.

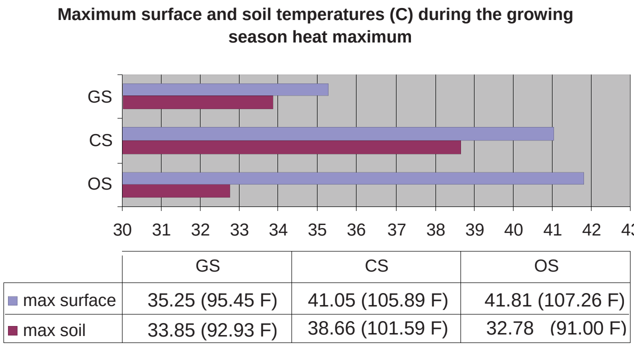


Fig. 3. Maximum surface and soil temps at sites for growing season (2006) during maximum heat period (7/19 to 8/2) showing insulating effect of soil/containers in system planters.

in Chicago over a growing season? 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. 4.a and Fig. 4.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. Two plants at CS and one plant at OS died during the growing season (Table 2). Although there was some early mortality, over the season survival rates were high at all sites.

J. horizontalis (Fig. 5) showed a reduction in overall width at all sites with the exception of CS and NS. 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 (Table 2), 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. 6.a), all sites with the exception of OS showed increases in plant height (Fig. 6.b). Some of the reduction in stem count can be attributed to

Table 1. Reservoirs through growing season for *R. copallina* at CS site[z]. 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									
Measure dates	**6/8**	**6/20**	**7/5**	**7/19**	**8/2**	**8/16**	**8/30**	**9/14**	**9/29**	**10/9**
Site-Plant ID	**Water reservoir levels in cm (1 cm ~ 0.40 in)**									
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

[z]Chicago Center for Green Technology.

Plant ID D1–D6: Experiment IDs for six replicates of *R. coppalina* at site.

Table 2. Overall survival of plant species showing number of plants (and percentage of original treatment) alive after growing season and after over wintering.

	Plant species survival rates							
	Number of plants and percentage of original treatment							
	R. copallina		***J. horizontalis***		***S. spectabile***		***S. scoparium***	
Site	**Growing season**	**Over winter**	**Growing season**	**Over winter**	**Growing season**	**Over winter**	**Growing season**	**Over winter**
GS	6 (100%)	2 (33%)	6 (100%)	6 (100%)	6 (100%)	5 (83%)	6 (100%)	5 (83%)
CS	4 (67%)	0 (0%)	6 (100%)	5 (83%)	6 (100%)	3 (50%)	6 (100%)	4 (67%)
OS	5 (83%)	1 (17%)	6 (100%)	6 (100%)	2 (33%)	1 (17%)	4 (67%)	1 (17%)
NS	6 (100%)	3 (50%)	6 (100%)	6 (100%)	6 (100%)	4 (67%)	6 (100%)	5 (83%)
SS	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	1 (17%)	1 (17%)

Sites:

GS: Garfield Park Conservatory modified CIPS planter system

CS: Chicago Center for Green Technology modified CIPS planter system

OS: OWP/P modified CIPS planter system

NS: Garfield Park Conservatory non-system planters

SS: Garfield Park Conservatory in soil

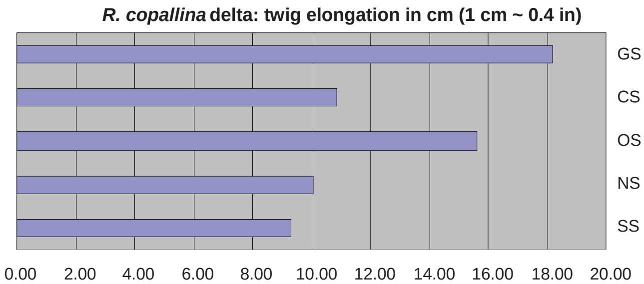


Fig. 4.a. ***R. copallina*** **average change in twig elongation over growing season (2006).**

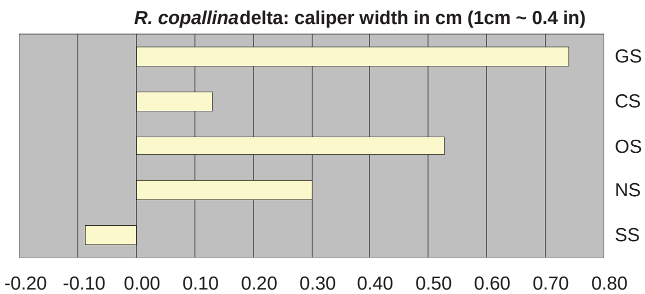


Fig. 4.b. ***R. copallina*** **average change in stem diameter over growing season (2006).**

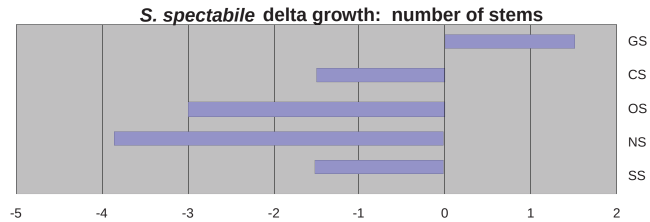


Fig. 6.a. ***S. spectabile*** **average change in number of stems over growing season (2006).**

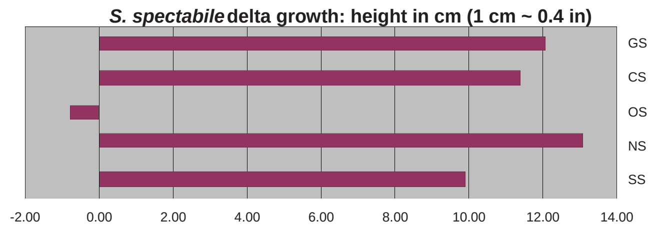


Fig. 6.b. ***S. spectabile*** **average change in plant height over growing season (2006).**

plants going dormant at the end of the growing season. Loss of plants at OS (Table 2) 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.

Plant clump diameters of *S. scoparium* (Fig. 7.a) changed slightly [1 cm (0.4 in)] at the system planter sites, GS, CS, and OS, and between 1 and 2 cm [0.4 and 0.8 in] at the NS site, while the large average change for the SS site is attributable to an early loss of plants at this site (Table 2). Average change in plant heights (Fig. 7.b) 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, NS and SS were located in a large urban park and so were susceptible to animal interactions, such as raccoons, rabbits and squirrels falling into planters, eating plants or digging into planters. The NS 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

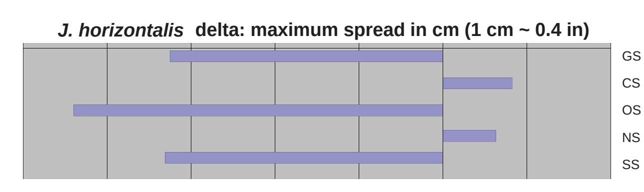


Fig. 5. ***J. horizontalis*** **average change in maximum spread over growing season (2006).**

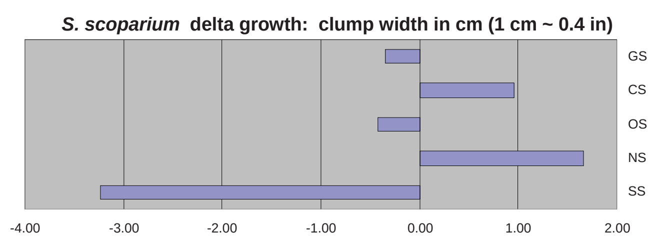


Fig. 7.a. ***S. scoparium*** **average change in clump diameter over growing season (2006).**

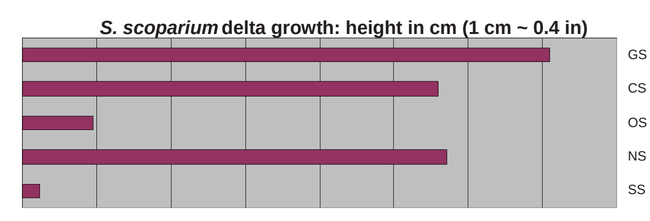


Fig. 7.b. ***S. scoparium*** **average change in plant height over growing season (2006).**

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. OS had the highest maximum temperature, reflecting the mid-city urban heat island effect, while GS had the lowest maximums during the season's heat peak suggesting a mitigating effect of the green park surroundings as well as the surfaces on which the planters rested.

Do plants in general survive over a Chicago winter season in containers designed using the modified CIPS model and how does survival correlate with temperature? 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).

At GS during the period of minimum temperatures in early February, the soil temperature was measured at approximately zero degrees 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 and OS during the same period of minimum temperatures, the soil temperature was also measured at approximately zero degrees different from the surface temperature and actually dropped below surface temperature until finally warming up. At NS, the control site with non-system planters, the soil temperature followed this same pattern.

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.

Do selected plant species survive a Chicago winter season in the modified CIPS systems at each location? 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 in 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.

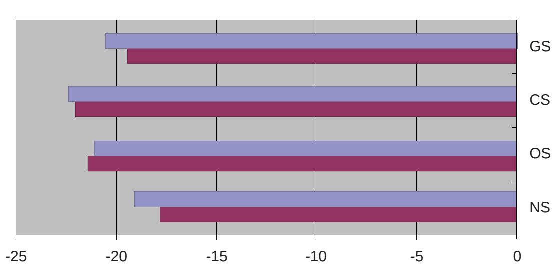
In conclusion, plant growth and mortality over the growing season varied, but with few exceptions all of the species did well. Plant survival rates in the planter systems were 83% for *R. copallina*, 100% for *J. horizontalis*, 78% for *S. spectabile*, and 89% for *S. scoparium*. Plants took up water from the planter reservoirs during the growing season and the planters, as designed, were replenished by rainwater through the summer.

All species lived through the winter season in the system planters, with *R. copallina* having the lowest overall survival rate of 20% of the plants alive at the end of the growing season. While the native range of *R. copallina* includes northeastern Illinois, its main range is further south and susceptibility to winter temperatures may be greater if the plants originally come from more southern stock. This, in addition to the stresses at the various sites which included herbicide spraying and storms, may have contributed to the lack of bud break on a high proportion of them as compared to the control group planted directly in soil. While some of these plants appeared to reach dormancy in the fall, others maintained green leaves through the end of September and did not appear to harden off.

The control site at which plants had been planted directly in soil had the highest over winter rates of survival. Surface and soil temperature comparisons through the winter season show that the planter design provided limited insulating effect. Average minimum temperature in the system planters was –21.3C (–6.4F), while the average minimum soil temperature at the control sites was –20.9C (–5.7F) indicating a slight lack of freezing protection to root systems in aboveground planters. This may have been due to the small size of the planters as well as the design which did not include any internal insulation of the plastic planters. Additional reasons for higher plant mortality in containers might include limited rooting space compared with the control plantings in soil, root pruning of some plants to allow them to fit the containers, more extreme temperature fluxes in both summer and winter, and deleterious differences in soil microbiota of the artificial soil. Additional research will be required to determine specific reasons for differences in mortality, though overall survival rates were good.

Two recommendations for design modification are suggested by this study. First, insulation added to the planter design, covering the planters, moving them to protected areas, 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,

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



	GS	CS	OS	NS
min soil	-20.57 (-5.03 F)	-22.35 (-8.23 F)	-21.1 (-5.98 F)	-19.08 (-2.34 F)
min surface	-19.4 (-2.92 F)	-22.04 (-7.67 F)	-21.4 (-6.52 F)	-17.75 (-0.05 F)

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.

there would be a related need to develop plant replacement packages in which the plants are sealed.

The planters, as designed for this experiment, were successful as a low maintenance greening system for urban residents. The plant material tested had high survival rates through the growing season, and the planter systems themselves required no additional watering after initial setup. Although perennials and woody plants were the test species in this study, the system planters lend themselves to use with annuals as well and could be utilized by urban residents to grow selected vegetables.

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