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Selecting Plants for Extensive Green Roofs in the United States

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What is a Green Roof?

Green roofs, or vegetated roofs, are an alternative roofing technology in which plant material is established on the rooftop. They provide numerous ecological and economic benefits, including stormwater management, energy conservation, mitigation of the urban heat island effect, increased longevity of roofing membranes, and mitigation of noise and air pollution. Green roofs also help provide an aesthetically pleasing environment to work and live in.

Green roofs are categorized as intensive or extensive systems. Intensive green roofs are similar to landscaping found at ground level, and require media depths greater than 6 inches and have intense maintenance needs. By contrast, extensive green roofs use shallower media depths (less than 6 inches) and require minimal maintenance. Because of the challenges of selecting plants for shallow media, this publication focuses on extensive green roofs.

Figure 1. A 10.4-acre extensive green roof in Dearborn, Mich. at the Ford Motor Co. River Rouge assembly plant.

Considerations for Plant Selection

Factors in selecting plant material are design intent, aesthetic appeal, environmental conditions, media composition and depth, installation methods and maintenance. Design factors that may influence plant selection include accessibility to and use of the roof, stormwater management objectives, xeriscaping objectives and thermal insulation objectives. Before selecting species on the basis of the design intent, expectations of aesthetics should be addressed because many species have dormant periods when the green roof may not appear so green. For example, many native prairie grasses and perennials will normally dry and brown in the summer. Although this is a natural occurrence, some may find it unacceptable.

Figure 2. An extensive green roof during dormancy in East Lansing, Mich.

Regardless of the desired aesthetic effect, climate and microclimate have a major impact on plant selection. In particular, average high and low temperatures, extreme hot and cold temperatures, irradiance levels, wind, and the amount and distribution of rainfall throughout the year will determine what species can survive in a specific area. Drought tolerance is important because high levels of solar radiation and low media moisture are usually the norm in shallow extensive systems. Likewise, microclimates on the roof must be considered. Roof slope and orientation may influence the intensity of the sun and media moisture content, surrounding structures may shade a portion of the roof, air vents from heating and air conditioning units may dry the media, and chemical exhaust from industrial buildings may influence plant growth. Environmental conditions, especially the amount and distribution of rainfall and temperature extremes, will eliminate the use of certain species or will dictate the need for irrigation. Although aesthetic appeal is an important criterion on many roofs, survival and stress tolerance are the primary criteria.

Media composition and depth have a major impact on plant selection for green roof systems. The ideal extensive green roof medium consists of a balance of lightweight, well-drained materials, possesses adequate water- and nutrient-holding capacity, and will not break down over time. Shallow media depths found on extensive green roofs dry out fast and usually do not support woody species, deep-rooted grasses, and many annual or perennial flowering plants. Conversely, shallow media often limit the growth of many undesirable weeds, and many desirable species are naturally found growing under these shallow conditions.

Figure 3. Typical extensive green roof medium.

In addition, installation method may influence plant choice. Plants can be established at ground level - grown as plugs or established on a blanket, mat or tray and then placed on the roof directly - or on the green roof medium via seed, plugs or cuttings. The availability of individual species in any of these forms may influence plant selection. In addition, the method of installation chosen may influence how much irrigation is required during initial plant establishment. And the long-term need of individual species for irrigation will also be an issue in plant selection.

Plant Characteristics

The variability of green roof designs and climates in the United States. makes it impractical to list every possible plant candidate for extensive green roofs. As a general rule, potentially suitable species can be found by looking at the microclimate (media depth, solar levels, water availability, etc.) of the green roof in question and comparing it to a plant's native habitat. Some species have evolved in extreme conditions, such as mountainous terrains, high altitude environments, coasts, limestone media or arid areas and are probably suitable for green roofs.

In choosing which plants to use, consider plant characteristics such as rate of establishment, longevity, ground cover density, and disease and pest resistance. The ideal species are long-lived and reseed themselves or spread vegetatively. Drought tolerance is one of the most limiting factors on extensive green roof systems because of their shallow media depths and usual reliance on natural precipitation. However, be careful to avoid drought-tolerant species that rely on deep taproots to obtain moisture – this situation cannot exist on a shallow extensive roof.

Succulent plants are well-adapted to the conditions often found on extensive green roofs because of their ability to limit transpiration and store excess water. Species such as *Sedum*, *Delosperma*, *Euphorbia* and *Sempervivum* are popular choices.

Presented here are species suggestions taken from scientific literature, as well as grower recommendations.

Figure 4. Green roof established with plugs.

Figure 5. Green roof established with seed.

Plants for Extensive Green Roofs in the United States**

Botanical name	Common name	Scientifically tested	State tested	Media depth tested (inches)	Grower recomm-ended?	Recommended region[z]	Notes[y]	Reference[x]
Achillea tomentosa	Western yarrow	X	OR	2-4			1	5
Agastache foeniculum	Blue giant hyssop	X	MI	4			2,4	9
Allium cernuum	Nodding wild onion	X	MI, WA	4,6	X	MW	2	3, 8, 9
Allium maximowiczii	Ornamental onion				X	MW		
Allium schoenoprasum	Ornamental onion				X	MW,NE		
Allium senescens	Ornamental onion				X	MW, MA, SE		
Allium stellatum	Prairie onion				X	MW		
Allium tanguticum	Ornamental onion				X	MW		
Antennaria neglecta	Pussytoes				X	MW		
Aquilegia canadensis	Red columbine				X	MW		
Arctostaphylos uva ursi	Kinnikinnick	X	MA, WA	5, 6			2	6, 8
Artemisia tridentata	Desert sage				X	NE	3	
Asclepias tuberosa	Butterfly milkweed				X	MW		
Asclepias verticillata	Whorled milkweed				X	MW		
Aster ericoides	Heath aster				X	MW		
Aster laevis	Smooth blue aster	X	MI	4			2,4	9
Aster oblongifolius	Aromatic aster				X	MW		
Bouteloua curtipendula	Side oat grama				X	MW		
Buchloe dactyloides	Buffalo grass				X	MW		
Carex flacca	Heath sedge	X	MI	4				3
Carex pensylvanica	Pennsylvania sedge				X	MW	2	
Carex radiata	Fox sedge				X	MW	2	
Cerastium tomentosum	Snow-in-summer	X	OR	2-4			1	5
Chrysanthemum vulgare	Ox-eye daisy				X	MW		
Convallaria majalis	European lily of the valley	X	MA	6			2	6
Coreopsis lanceolata	Lanceleaf coreopsis	X	MI	4			2,4	9
Coreopsis palmata	Tickseed				X	MW		
Coreopsis rosea	Pink tickseed	X	MA	6				6
Dalea purpurea	Purple prairie clover	X	MI	4	X	MW	4	9
Danthonia spicata	Poverty oatgrass	X	MA	6				6

Botanical name	Common name	Scientifically tested	State tested	Media depth tested (inches)	Grower recomm-ended?	Recommended region[z]	Notes[y]	Reference[x]
Delosperma congestum	Ice plant				X	NE		
Delosperma cooperii	Ice plant	X	OR	2-4	X	NE		5
Delosperma nubigenum	Ice plant	X	NC, OR	2-6, 2-4	X	MA, SE, NE		5,10
Deschampsia flexuosa	Wavy hairgrass				X	NE	3	
Dianthus deltoides	Maiden pink				X	MA,SE	1	
Elymus elymoides	Bottlebrush grass				X	NE	3	
Epimedium perralderianum	Epimedium	X	MA	6			2	6
Eragrostis spectabilis	Purple lovegrass				X	MW		
Eryngium yuccifolium	Button eryngo			3	X	MW		
Euphorbia myrsinites	Myrtle spurge				X	MW		
Festuca glauca	Blue fescue	X	OR	4	X	NE		5
Festuca ovina	Sheep fescue				X	MA,SE, NE	1, 3	
Fragaria virginiana	Wild strawberry	X	MI	4	X	MW	2, 4	9
Gaultheria procumbens	Eastern teaberry	X	MA	6			2	6
Geum triflorum	Prairie smoke				X	MW		
Gilia capitata	Bluefield gilia	X	OR	2-4			1	5
Heuchera americana	American alumroot				X	MW		
Heuchera villosa	Hairy alumroot	X	MA	6			2	6
Jovibarba species	Hens and chicks				X	MW, NE		
Juncus effusus	Common rush	X	MI	4			2,4	9
Koeleria macrantha	Prairie Junegrass	X	MI	4	X	MW	2,4	9
Liatris aspera	Tall blazing star	X	MI	4			2,4	9
Lobelia siphilitica	Great blue lobelia	X	MA	6			2	6
Lupinus bicolor	Miniature lupine	X	OR	2-4			1	5
Lysimachia clethroides	Gooseneck yellow loosestrife	X	MA	6			2	6
Maianthemum canadense	Canada mayflower	X	MA	6			2	6
Monarda punctata	Spotted beebalm	X	MI	4			2,4	9
Muscari species	Grape hyacinth	X	OR	2-4			1	5
Nierembergia	Cup flower	X	OR	2-4				5
Oenothera macrocarpa	Bigfruit evening primrose				X	MW		
Opuntia humifusa	Prickly pear	X	MI	4	X	MW, NE	3	9
Pachysandra procumbens	Allegheny spurge	X	MA	6			2	6

Botanical name	Common name	Scientifically tested	State tested	Media depth tested (inches)	Grower recomm-ended?	Recommended region[z]	Notes[y]	Reference[x]
Penstemon hirsutus	Beardtongue				X	MW		
Petrorhagia saxifraga	Saxifrage pink	X	PA	2-5				11
Phedimus spurius	Caucasian stonecrop	X	MA, MI	6, 1-4			2	1, 6, 9
Potentilla anserma	Cinquefoil	X	MI	4	X	MW	2,4	9
Potentilla neumaniana	Cinquefoil	X	OR	2-4			1	5
Rudbeckia hirta	Black-eyed Susan	X	MI	4			2,4	9
Ruellia humilis	Wild petunia				X	MW		
Schizachyrium scoparium	Little bluestem	X	MI, MN	4, 2-6	X	MW	2,4	7, 9
Sedum acre	Biting stonecrop	X	MI, OR	1-6, 2-4	X	MA, SE, MW, NE		1, 3, 5, 9
Sedum aizoon	Stonecrop				X	NE		
Sedum album	White stonecrop	X	MI, NC, OR, PA	1-6, 2-6, 2-4, 1-6	X	MW,NE,MA,SE		1, 3, 5, 9, 10, 11
Sedum anacampseros	Stonecrop				X	NE		
Sedum cauticola	Stonecrop	X	MI		X	MW, NE	4	2
Sedum cyaneum	Stonecrop				X	NE		
Sedum dasyphyllum	Thick-leaved stonecrop	X	MI	1-3			1	1
Sedum diffusum	Stonecrop	X	MI	1-3			1	1
Sedum divergens	Cascade stonecrop	X	MI, OR	2-4	X	MW	4	3, 5
Sedum ellacombianum	Orange stonecrop	X	MI	4	X	MA,SE, MW, NE		9
Sedum ewersii	Stonecrop	X	MI	1.5-4	X	NE	1	2
Sedum floriferum	Stonecrop	X	MI, NC	2-4, 2-4	X	MA, SE, MW, NE		2, 10
Sedum grisbachii	Stonecrop				X	MW, NE		
Sedum hispanicum	Spanish stonecrop	X	MI, OR	2-4, 2-4	X	NE	1	1, 2
Sedum hybridum	Hybrid stonecrop				X	MA,SE		
Sedum japonicum	Stonecrop				X	NE		
Sedum kamtschaticum	Orange stonecrop	X	MI, OR	1-4, 2-4	X	MA, SE, MW, NE		1, 4, 5, 9
Sedum lydium	Stonecrop				X	NE		
Sedum matrona	Stonecrop				X	MA,SE	1	
Sedum middendorfianum	Stonecrop	X	MI	1-3	X	MW, NE		1,9
Sedum oreganum	Oregon stonecrop	X	OR	2-4	X	MW,NE	3	5

Botanical name	Common name	Scientifically tested	State tested	Media depth tested (inches)	Grower recomm-ended?	Recommended region[z]	Notes[y]	Reference[x]
Sedum pachyclados	Stonecrop				X	MW,NE		
Sedum populifolium	Stonecrop				X	NE		
Sedum pulchellum	Bird's claw sedum	X	MI	4	X	MW,NE	2,3	3, 9
Sedum reflexum	Crooked stonecrop	X	MI, NC, OR	2-4, 2-6, 2-4	X	MA,SE,MW	1	1, 2, 3, 5, 10
Sedum rupestre 'Angelina'	Stonecrop	X	MI	2-4			1	2
Sedum sarmentosum	Stringy stonecrop	X	MI	2-4	X	NE		2
Sedum sediforme	Pale stonecrop	X	MI	2-4	X	NE		1, 2
Sedum sexangulare	Tasteless stonecrop	X	MA, MI, NC, OR, PA	6, 2-4, 2-4, 1-5	X	MA, SE, MW, NE		2, 4, 5, 6, 10, 11
Sedum sieboldii	Stonecrop				X	MW, NE		
Sedum spathifolium	Broadleaf stonecrop	X	OR	2-4	X	MW		5
Sedum spectabile	Showy stonecrop				X	MW		
Sedum spurium	Creeping sedum	X	MI, NC, OR	1-4, 2-4, 2-4	X	MA, SE, MW, NE		1, 2, 3, 4, 5, 9, 10
Sedum stefco	Stonecrop	X	MI	2-4	X	MA, SE, MW		2
Sedum stenopetalum	Narrow-petaled stonecrop	X	MI		X	MW	4	3
Sedum tatarinowii	Stonecrop				X	NE		
Sedum telephium	Stonecrop	X	OR	2-4	X	MW,NE		5
Sedum ternatum	Woodland stonecrop	X	MA	6	X	MW, NE	2,3	6
Sedum tetractinum	Chinese sedum				X	NE		
Sedum urvillei	Stonecrop	X	MI				4	3
Sempervivum species	Hens and chicks				X	MA,SE, MW, NE		
Sempervivum tectorum	Common houseleek	X	OR	2-4			1	5
Sisyrinchium angustifolium	Blue-eyed grass				X	MW		
Solidago nemoralis	Gray goldenrod	X	MN	2-6				7
Sporobolus heterolepsis	Prairie dropseed	X	MI	4	X	MW	2,4	9
Talinum calycinum	Fameflower	X	MI		X	MA,SE, NE	1, 3	3
Tradescantia ohiensis	Spiderwort	X	MI	4				9
Viola pedata	Bird's-foot violet				X	MW		

[z]:MA= Midatlantic, SE=Southeast, NE=Northeast, MW=Midwest

[Y]: 1=accent plant, 2=suitable for shade, 3=native to U.S., 4=may need irrigation for survival. [X]: See references (next page).

**NOTE: Any species listed here may perform differently depending on the specific micro- and macro-environmental conditions of the roof.

Little has been published for species tested in southern portions of the United States. However, scientists in Singapore (likely comparable to a U.S. hardiness zone of 10 or 11) have found the following species to be thriving on a 2- to 4- inch deep roof: *Aglaia odorata, Aloe vera, Aptenia cordifolia, Callisia repens, Carpobrutus edulis, Delosperma lineare, Furcraea foetida, Ixora coccinea, Kalanchoe tomentosa, Liriope muscari, Lonicera japonica, Murraya paniculata, Ophiopogon intermedius, Pandanus amaryllifolius, Portulaca grandiflora, Sanseveria trifasciata, Sedum acre, Sedum mexicanum, Sedum nussbaumerianum, Sedum sarmentosum, Sedum sexangulare, Tradescantia pallida, Zephyranthes candida* and *Zephyranthes rosea.*

In addition, the following species are currently being tested in southern regions of the United States. No results have yet been published, but they serve as a good starting point for extensive green roofs in these regions. In Florida, with 5 inches of media, the following species are being tested: *Gaillardia pulchella, Liatris spicata, Sisyrinchium atlanticum, Coreopsis grandiflora, Helianthus debilis, Licania michauxii, Phyla nodiflora, Muhlenbergia capillaris, Arachis glabrata* and *Salvia coccinea*. In Texas, with 4 inches of medium, the following species are being tested: *Bouteloua curtipendula, Bouteloua gracilus, Bouteloua rigidisete, Carex texensis, Nassella tenuissima, Panicum hallii, Bignonia capreolata, Dalea greggii, Erigeron modestus, Hesperaloe parviflora, Manfreda maculosa, Salvia farinacea, Salvia greggii, Scutellaria wrightii, Stemodia lanata* and *Tetraneuris scaposa.*

In California, a statewide effort to increase energy efficiency of buildings is under way. The creators of that outreach campaign suggest the following species may work on an extensive green roof in the Los Angeles area: *Aloe nobilis, Carex stricta, Carex testacea, Delosperma alba, Delosperma cooperii, Dudleya hassei, Dudleya pulverulenta, Echinocactus grusonii, Kalanchoe beharensis, Lampranthus deltoides, Lampranthus productus, Muhlenbergia rigens, Opuntia basilaris, Opuntia violacea santarita, Sedum sieboldii* and *Sedum spathulifolium.*

Other Resources

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- The Green Roof Research Program at Michigan State University Web site: www.hrt.msu.edu/greenroof/.
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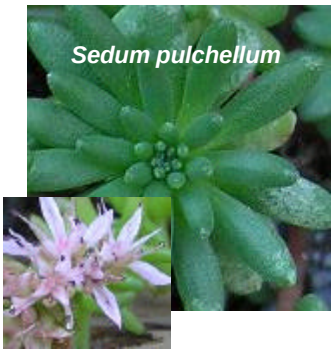

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