An Evaluation Study of Plants for Use on Green Roofs

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The significance of green roofs in urban areas has steadily increased over the past 20 years. In the United States, as well as worldwide, green roofs have become vital components of new construction on a broad variety of buildings, from municipal to commercial and industrial to residential. The benefits of green roofs are measured in environmental, economic, and aesthetic or cultural ways. In its simplest form, a green roof may contain a sampling of sedums or other hardy succulents, but many modern green roofs have increased the range and diversity of plants being grown by installing deeper growing media and changing the way green roofs are viewed or utilized. Whether strictly utilitarian or highly specialized and ornamental, green roofs have a variety of benefits over a traditional roof.

The environmental benefits include conserving water, reducing interior noise pollution, mitigating stormwater runoff, reducing the urban heat-island effect, improving urban air quality through carbon dioxide-oxygen exchange, and creating habitats for a diversity of birds, insects, and animals. Along with extending the life of the roof by two to three times over a conventional roof, economic benefits include reducing energy costs—both heating and cooling—increasing property values, and meeting requirements for stormwater management. Providing an aesthetic amenity space for building occupants and pleasing views from within or from a distance, creating green space in urban environments, attracting wildlife, and growing food crops are all cultural benefits of green roofs.

While the type of green roof is based on the building and user needs, green roofs are increasingly being developed for their cultural aspects, that is, it is becoming more common for green roofs to provide interactive and amenity space for building occupants or the general public. With this usage comes a desire to have greater plant diversity so that the green roof functions on an environmental level as well as provides a pleasing landscape. Green roofs are classically described by the depth of the growing medium—extensive, semi-intensive, and intensive. Extensive green roofs have a growing depth of 3 to 6 inches, and are typically lighter in weight with a saturated weight of 15 to 30 pounds per square foot. This fairly shallow growing medium supports a limited plant palette, often kept to

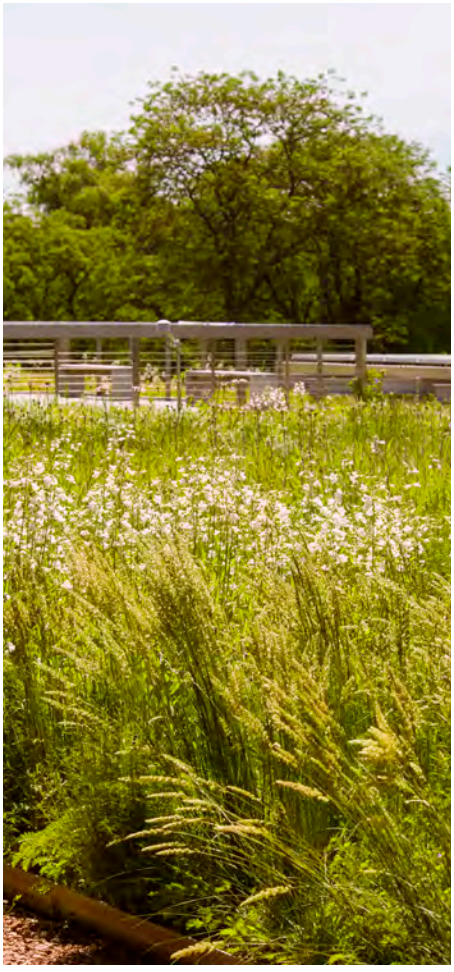
drought-tolerant hardy succulents. Extensive green roofs are popular with homeowners and large industrial, commercial, and municipal buildings where the environmental and economical benefits are most valued. Semi-intensive green roofs are a heavier system, with a saturated weight of 30 to 50 pounds per square foot, and a growing medium of 6 to 12 inches. The greater growing depth supports a wider variety of perennials, grasses, and shrubs, which creates a more gardenlike landscape. Depending on the regional climate, irrigation may be necessary and more maintenance may be required to keep the semi-intensive green roof looking good. With a saturated weight greater than 70 pounds per square foot, intensive green roofs are the heaviest and have growing depths greater than 12 inches. This type of roof is commonly designed for access by people, supports shrubs and trees, and has higher maintenance needs.

When choosing plants for green roofs it is important to understand that a green roof is not the equivalent of a typical landscape elevated to the top of a building; therefore, appropriate consideration must be given to a plant's growth habit, native ecosystem, and cultural needs, to name a few factors. Many common garden plants will not survive on a green roof. In *Green Roof Plants,* Ed and Lucie Snodgrass succinctly describe the ideal traits for a good green roof plant—"The most successful green roof plants are low-growing, shallow-rooted perennial plants that are heat, cold, sun, wind, drought, salt, insect, and disease tolerant. Green roof plants should also have a long life expectancy or the ability to self-propagate, and they should require minimal nutrients and maintenance." Needless to say, selecting the right plants for green roofs is anything but simple. The Snodgrasses' words bear out the challenge of finding plants suited to the harsh growing conditions on green roofs.

The Chicago Botanic Garden's Green Roof Garden

In September 2009, the Chicago Botanic Garden opened its Daniel F. and Ada L. Rice Plant Conservation Science Center, a 38,000-square-foot LEED Gold-rated research and laboratory facility designed by Booth Hansen, a Chicago-based architectural firm. Atop the Center is a 16,000-square-foot green roof, divided into two 8,000-square-foot gardens that display a variety of North American native plants and exotic plants from around the world. The Green Roof Garden of the Chicago Botanic Garden consists of the Josephine P. & John J. Louis Foundation Green Roof Garden North and the Ellis Goodman Family Foundation Green Roof Garden South. The Green Roof Garden is both a living laboratory and a beautifully designed garden enjoyed by visitors year-round.

North green roof



Koeleria macrantha and *Penstemon digitalis*

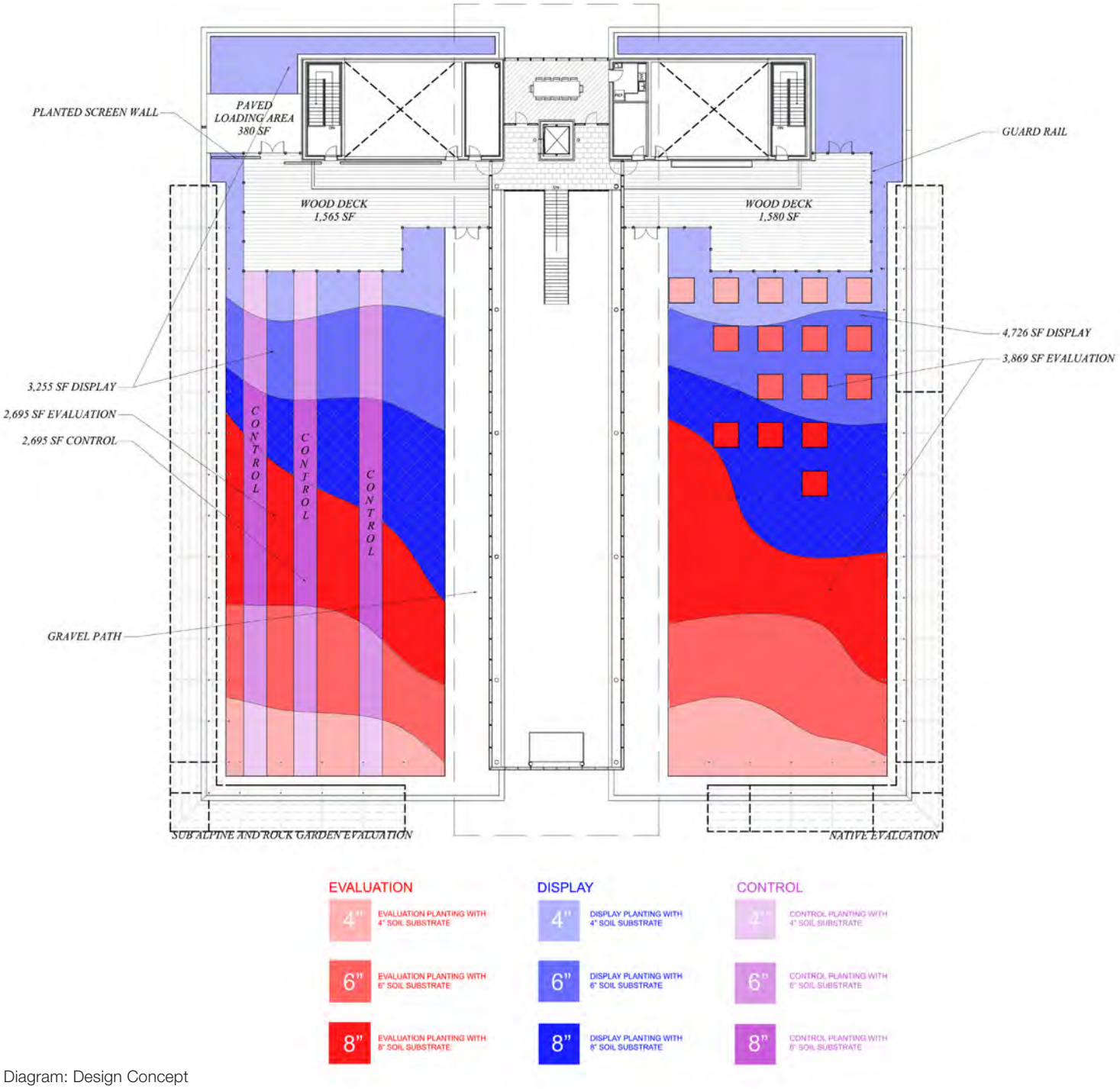


Diagram: Design Concept

The green roof gardens have a two-fold purpose: to display the best plants for green roofs and to trial untested plants for their adaptability to this environment. Following an initial five-year evaluation phase, new trials of uncommon and/or untested plants will continually cycle into the green roof gardens. The ultimate goal of the trial is to develop a diverse and extensive list of recommended plants for green roof culture. Greater biodiversity supports the aesthetic design of a green roof as well as creating a habitat for a variety of beneficial pollinators and wildlife.

Our green roof gardens were designed by Oehme, van Sweden Landscape Architecture (OVS), Washington, D.C., and feature their signature combinations of herbaceous plants to create a succession of ornamental traits throughout the seasons. For example, generous sweeps of lesser calamint *(Calamintha nepeta* ssp. *nepeta)* and Russian sage *(Perovskia atriplicifolia)* are interplanted to contrast and complement each other in flower and form; and goldenrod (*Solidago* 'Wichita Mountains') and reed grass *(Calamagrostis brachytricha)* are paired perfectly so that the goldenrod's bright yellow flowers glow through the delicate seedheads of the grass in autumn.

The two 8,000-square-foot green roofs, located on the north and south sides of the building's central clerestory, are differentiated by their plant palettes and bed designs. Each of the green roofs is divided in half into display and evaluation areas, and then each area is further divided into beds with 4, 6, and 8 inches of growing medium (see Diagram). At these growing depths, the green roof is within the extensive to semi-intensive range. Curvilinear aluminum bands—both decorative and structural—run from north to south across the roofs, delineating the spaces between the three growing depths. The growing medium is a mixture of expanded clay and shale, vermiculite, perlite, sand, and organic matter.

The north green roof features native and nonnative plants, as well as a variety of sedums (*Sedum* spp.) planted in three linear ribbons that bisect the roof from east to west. The sedum plantings are meant to draw the eye across the roof using color, texture, and form to create the feeling of movement, and to act as an experimental control, since sedums are the workhorses on extensive green roofs. The intersection of the curved and straight lines creates a compartmentalized effect, giving the north green roof a pleasing patchwork appearance that from the beginning appealed to visitors.

North green roof display beds

Sedum strip on north green roof

North American native plants, at the species level, inhabit the south green roof. Here, the gently curving beds are not interrupted by sedum strips, so this roof is less compartmentalized, allowing for greater sweeps of plants. The overall look is naturalistic, resembling a prairie or meadow landscape. Superimposed on the display area are 16 evaluation squares—6- by 6-foot boxes flush with the surface of the growing medium but separated from the display plantings by metal edging. Within each square are nine GreenGrid modules—black plastic trays that contain a variety of plants replicated in each of the three growing depths. The squares are visible from the visitor viewing deck to demonstrate the evaluation process that is taking place in the nonaccessible areas of the roof.

The custom-designed roof is composed of a series of layers from the growing medium down to the roof membrane. The base of the green roof starts with a ⅝-inch gypsum

board overlaid with an Electric Field Vector Mapping (EFVM) system—EFVM grounding screens use low-voltage electrical pulses to detect breaches in the waterproofing membrane. A felt pad covers the EFVM, and the Samafil waterproofing membrane is laid down next. EFVM conductors are then placed along the perimeter of the roof and another felt pad covers them. Continuing upward, extruded polystyrene insulation, a water retention mat, and a water drainage panel make up the next three layers, respectively. The drainage panel channels water to the central roof drain that empties into a bioswale surrounding the building. Filter fabric covers everything, and the growing medium is the final layer.

While there was no official monitoring of wildlife in the green roof gardens, it has clearly become a habitat for a variety of birds and insects. Killdeer have regularly nested on the green roof since the first spring of 2010; mallard ducks, robins, swallows, hummingbirds, mourning doves, and sparrows are common visitors to the green roof gardens. Furthermore, a variety of bees, butterflies, ants, and other insects have been observed.

Shadow line on north green roof in late summer-early fall

The Evaluation Study

The Chicago Botanic Garden (USDA Hardiness Zone 5b, AHS Plant Heat Zone 5) planted 156 taxa of herbaceous and woody taxa on the green roof in 2009, and an additional 60 taxa in 2011. The trial included both native North American taxa and nonnative species and cultivars. Initially, the proposed plant list was informed by regional research on green roof plants undertaken at Michigan State University, East Lansing, Michigan; Intrinsic Landscaping, Glenview, Illinois; and Midwest Groundcovers, St. Charles, Illinois. The evaluation taxa were selected for their potential to succeed in the temperature and moisture extremes typical on a green roof. While some taxa had been grown on green roofs in other regions, a portion of the taxa were new or uncommon on green roofs. The goal of the trial was to develop a diverse list of recommended plants for use on green roofs.

Photo by Winston Beck

Antennaria dioica floral detail

Photo by Nathaniel Kahn

Antennaria dioica

Unlike a typical comparative trial undertaken at the Chicago Botanic Garden, the broad diversity of the plant list was the equivalent of comparing apples to oranges. Instead, taxa were evaluated independently rather than comparatively unless a specific taxon was replicated in more than one location, more than one species in a genus was present, or plants had a similar life form, such as grasses. Although the majority of taxa were grown in just one location, 77 taxa were planted in two or more growing depths. Of those 77 taxa, 31 taxa were planted in all three of the growing depths. Plant quantities per taxon varied from several to more than 3,000, depending on the way a plant was used in the design. For example, large sweeps of *Koeleria glauca* and *Coreopsis lanceolata* were more significant than plants that were used as accents such as *Iris tectorum* or *Salvia officinalis*. With

Photo by Nathaniel Kahn

Juniperus chinensis var. *sargentii* 'Viridis'

Photo by Winston Beck

Calamintha nepeta ssp. *nepeta*

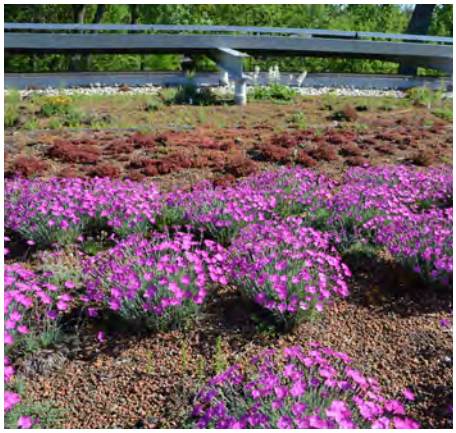


Photo by Allison Hurt

Dianthus gratianopolitanus 'Firewitch'

the exception of a strip of shade—created by the building's clerestory—parallel to the southern edge of the north roof, the green roofs were in full sun. Depending on the time of year, the shaded strip was several inches to several feet wide.

Prior to planting in August 2009, the growing medium, which is a mixture of expanded clay and shale, vermiculite, perlite, sand, and five percent organic matter, had a pH of 7.4. In November 2010, one year after planting, organic matter averaged 5.3 percent and the average pH had risen to 7.8. Soil tests in April 2015, following the completion of the trial, showed an organic matter range of 3.2 percent to 6.9 percent and a pH range from 7.0 to 7.6. Of the 12 testing sites, four saw increases in organic matter, ranging from 6.5 percent to 6.9 percent. In the native plantings on the south green roof, organic matter was typically highest in the 6- or 8-inch plots, reaching 6.9 percent; whereas, in the nonnative plantings 6 percent organic matter was noted in the 4-inch evaluation plot, while the lowest, 3.8 percent, was noted in the 8-inch display plot.

Minimal maintenance was provided, mainly to ensure plant survivability during periods of severe drought and to preserve the integrity of the design. Plants were regularly irrigated in August and September of 2009 to establish them after planting. In subsequent years, water was provided on a limited basis only during extreme droughty periods. Selective weeding occurred in all years of the trial to remove unwanted seedlings and invading species. Weed species entered the roof in two ways: as plants or seeds contained in the production vessel at planting time, or dispersed by wind or birds after planting. In the early years, common weeds included woodsorrel, clover, chickweed, dandelion, alder, and cottonwood. Woodsorrel and clover remained the most troublesome weed species throughout the trial years. In addition, reseeding of trial plants was monitored, with excessive seedlings removed as necessary. All herbaceous plants were mowed to the ground in late winter and plant debris was removed. Moreover, plants were not fertilized, winter-mulched, or chemically treated for insect or disease problems at any time.

Performance Report

Between 2010 and 2014, 216 herbaceous and woody taxa were evaluated in the green roof gardens, 129 taxa on the north roof and 87 taxa on the south roof. Data collection for the 156 taxa planted in August 2009 commenced in April 2010; 60 additional taxa started their trial in June 2011. A combined total of 41,561 individual plants were planted on the green roof in 2009 and 2011.

All plants were evaluated for their 1) cultural adaptability to the growing medium and environmental conditions on the green roof; 2) disease and pest problems; 3) winter hardiness or survivability; and 4) ornamental qualities associated with flowers, foliage, and plant habit. In addition, plants were monitored for reseeding and weediness. Final performance ratings are based on plant health and vigor, survivability and longevity, habit quality and flower production,

Phlox subulata 'Emerald Blue'

and winter hardiness during the evaluation period (see Table 1).

Nine taxa received five-star excellent ratings for their overall performance and survivability, including *Antennaria dioica, Calamintha nepeta* ssp. *nepeta, Juniperus chinensis* var. *sargentii* 'Viridis', *Phlox subulata* 'Apple Blossom', *Phlox subulata* 'Emerald Blue', *Phlox subulata* 'Snowflake', *Rhus aromatica* 'Gro-Low', *Sporobolus heterolepis,* and *Sporobolus heterolepis* 'Tara'. Top-rated plants consistently displayed good vigor and robust habits, superior ornamental qualities, disease resistance, heat and drought tolerance, and winter hardiness/survivability throughout the evaluation period. Additionally, 69 taxa received four-star good ratings for their strong performances.

Early success for a portion of the taxa was evident by the end of the first full growing season in 2010. Among the taxa that established quickly and remained consistently healthy and vigorous throughout the full trial period were *Amorpha canescens, Andropogon gerardii, Antennaria dioica, Bouteloua curtipendula* (in 8 inches), *Calamagrostis brachytricha, Calamintha nepeta* ssp. *nepeta, Dalea candida, D. pupurea, D. villosa, Dianthus gratianopolitanus* 'Firewitch', *Festuca amethystina* 'Superba', *Geum triflorum* (in 6 inches), *Helianthus mollis, Heuchera richardsonii, Hieraceum spilopheum* 'Leopard', *Hosta lancifolia, Juniperus chinensis* var *sargentii* 'Viridis', *J. horizontalis* 'Wiltonii', *Koeleria glauca, K. macrantha, Nepeta racemosa* 'Walker's Low', *Penstemon digitalis* (in 6 and 8 inches), *P. hirsutus, P. hirsutus* 'Pygmaeus', *Phlox bifida, P. subulata* 'Apple Blossom', *P. subulata* 'Emerald Blue', *P. subulata* 'Snowflake', *Potentilla arguta* (in 8 inches), *Rhus aromatica* 'Gro-low', *Rosa carolina, Schizachyrium scoparium, Scilla numidica, Sedum hybridum* 'Immergrunchen', *S. kamtschaticum* ssp. *ellacombianum, S. kamtschaticum* var. *floriferum* 'Weihenstephaner Gold', *S. spurium* 'John Creech', *S. spurium* var. *album* 'Leningrad White', *Solidago rigida, S.* 'Wichita Mountains', *Sporobolus heterolepis, S. heterolepis* 'Tara', *Tetraneuris herbacea,* and *Viola sagittata. Coreopsis lanceolata* was a robust, heavy-bloomer in all locations between 2010 and 2013, but suffered huge

Photo by Allison Hurt

Galium verum

Photo by Heidi Petersen

Hieraceum spilophaeum 'Leopard' and *Schizachyrium scoparium* 'Little Luke'

South green roof

losses in the 6- and 8-inch plots in the winter of 2013–14. Only the plants in the 4-inch plots were alive in 2014. Despite *Coreopsis lanceolata* being somewhat short-lived, its performance between 2010 and 2013 was commendable nonetheless.

Some taxa were consistently healthy but either slower to establish, slow to increase in size, and/or more affected by environmental conditions; however, by the end of the trial all of these taxa were good performers. *Amorpha nana* took five years to become a substantial size, although it remained irregular in habit; *Asclepias tuberosa* was very slow-growing; *Baptisia alba* var. *alba* was few-stemmed and open until the fifth season; *Campanula rotundifolia* was slow to bulk up until the third year; *Coreopsis verticillata* 'Zagreb' always had a loose habit; *Eryngium yuccifolium* was very slow to gain size; *Fragaria virginiana* was slow to begin spreading and its stolons were continually damaged during hot, droughty periods; *Galium verum* was not vigorous until the third season, except for its seedlings; *Heuchera micrantha* 'Palace Purple' grew fairly well but off-colored dramatically in hot weather; *Iris tectorum* grew best in the shadier section of the bed; *Lespedeza capitata* was spindly for a couple of years; *Liatris ligulistylis* was slow to bulk up, often only single-stemmed; *Oligoneuron album* was fairly static until third year when it began to reseed widely, and the seedlings were more vigorous than the original plants; *Perovskia atriplicifolia* was a bit loose in habit; *Petrorhagia saxifraga* 'Rosea' was healthiest interplanted with *Phlox subulata* 'Emerald Blue', whereas it lacked vigor on its own; *Potentilla fruticosa* was rarely bushy, being loose and uneven in habit; *Pycnanthemum virginianum* remained loose and often single-stemmed; *Salvia* ×*sylvestris* 'East Friesland' never gained any size; *Symhyotrichum ericoides* 'Snow Flurry' stayed prostrate and never developed arching stems like it does in a garden; *Symphyotrichum sericeum* had an open to spindly habit; *Talinum calycinum* was slow to establish until it began to reseed; *Thymus praecox* 'Coccineus' did not become vigorous until the third year; and *Tradescantia tharpii* was slow to increase in size. *Oenothera fruticosa* 'Fireworks' and *Oenothera macrocarpa* were strong performers for three years but unexpectedly began to decline and die out in 2013.

Environmental conditions, especially excessive heat and drought, were closely monitored to determine how they affected the health, vigor, and survivability of the plants. Together or alone, heat and drought resulted in weakened plant health, partial vegetative loss, premature dormancy, and/or death. In many instances, plants weakened by environmental conditions during the growing season subsequently died in winter. At the outset of the trial it was decided that irrigation beyond establishment would be restricted unless deemed necessary to ensure the survival of the green roof plantings. Between 2010 and 2014, irrigation was provided three times during periods of extreme heat and drought; the green roofs were irrigated once in July 2011, June 2012, and July 2013 for 30 minutes each time. All plants were impacted by drought in varying degrees at some time each summer, but plants growing in 4 inches were generally most affected and showed signs of drought stress first (see Table 1). Regardless of growing depth, *Geum triflorum* appeared to be the best indicator plant for drought, always being the first to show signs of heat and drought stress. Drought was never severe enough for *Geum*

triflorum to go dormant or for more than a few plants to die, and health and vigor improved quickly once the droughty period was over. The leaves of *Symphyotrichum novae-angliae, S. oblongifolium, Echinacea pallida, Monarda fistulosa, Potentilla arguta,* and *Pycnanthemum virginianum* withered from the bottom up during hot, dry periods; the more severe the drought, the greater the leaf loss. *Aquilegia canadensis* went dormant in the hottest periods, and *Viola sagittata* stalled during droughty periods but rebloomed once moisture was available. *Andropogon gerardii* and *Bouteloua curtipendula* seemed to be adaptable to dry conditions, but most of their lower leaves turned brown; *Bouteloua curtipendula* in 4 inches generally lacked vigor and some plant losses were noted in droughty periods. Conversely, *Koeleria macrantha, Sporobolus heterolepis*, and *S. heterolepis* 'Tara' off-colored the least during unfavorable conditions; however, *Sporobolus heterolepis* and 'Tara' showed earlier fall color following droughty periods. Summer dormancy of foliage was observed on *Allium cernuum, Anemone caroliniana, Pulsatilla patens, Tradescantia ohiensis,* and *T. tharpii.* In general, all plants rebounded well after rain or irrigation.

A number of unique microclimates were observed on the green roofs, such as intermittent shade, localized incidental moisture, mechanical damage, and increased fertility. The green roof gardens received full sun throughout the year except for an area along the southern edge of the north roof, where the shadow from the atrium clerestory created some shade. The shadow was at its narrowest in mid- to late June, when only a few inches of shade was provided, and up to 4 feet wide when the sun was lower in the sky. A few taxa were specifically sited to take advantage of the shade—*Hosta* 'Cracker Crumbs', *Hosta lancifolia, Pachysandra procumbens,* and *Sedum ternatum* 'Larenim Park'. Shade encroached on a number of other taxa at various times in the growing season, resulting in a portion of the shaded plants being larger and lusher than their counterparts in full sun. In these cases, plant size differences ranged from slight to significant for the following taxa: *Gypsophila repens* 'Roseum', *Hosta* 'Cracker Crumbs', *Sedum ternatum* 'Larenim Park', *Hosta lancifolia, Prunella grandiflora, Koeleria glauca, Calamagrostis brachytricha, Calamintha nepeta* ssp. *nepeta, Perovskia atriplicifolia, Sesleria caerulea,* and *Solidago* 'Wichita Mountains'.

Conversely, a few of the taxa that received intermittent shade had plants that were smaller, looser, and less vigorous in the shade than in the sunny areas. Taxa with plants that were larger in full sun included *Antennaria dioica, Linum flavum* 'Compactum', *Scutellaria alpina, Sempervivum* 'Le Clair's Form', *Eriogonum umbellatum, Lavandula angustifolia* 'Hidcote', and *Scutellaria alpina.* The shade strip also parallels the dripline of the clerestory roof, which allowed for additional moisture from rainwater runoff to splash off the adjacent gravel pathway into the bed. All or some portion of the aforementioned taxa closest to the bed edge received additional moisture during rain events, but this incidental moisture was not measured or quantified. The combination of the shade and extra moisture likely caused the increase in plant size. The lush growth in the 8-inch plot on the south roof was attributed to the leguminous species growing there—sweeps of *Dalea candida, D. purpurea,* and *Lespedeza capitata* are planted with *Ceanothus americanus, Andropogon gerardii,* and *Pulsatilla patens.* The health and vigor of plants in this area surpassed all other areas on either green roof.

Several *Sedum* species did not perform as well as expected, given that sedums are considered reliable green roof plants. One possible reason for the subpar performance of *S. acre* 'Aureum', *S. album, S. album* 'Chloroticum', and *S. album* 'Coral Carpet' was because all foot traffic across the green roof had to step into sedum plots, making it nearly impossible not to trample plants and compact the growing medium. These taxa lacked the vigor to bounce back like some other sedums such as *S. hybridum* 'Immergrünchen', *S. sexangulare,* and *S. spurium* 'John Creech'. While *Sedum pachyclados* and *Hylotelephium sieboldii* may have suffered from foot traffic, they sustained their greatest plant losses in winter, and generally

Photo by Nathaniel Kahn

Tetraneuris herbacea

Helianthus mollis

Photo by Winston Beck

Hosta lancifolia

seemed less suitable to growing on the green roof. Several taxa with woolly leaves, including *Cerastium tomentosum, Stachys byzantina* 'Big Ears', *S. byzantina* 'Silver Carpet', and *Thymus pseudolanuginosus,* suffered during periods of high nighttime humidity, causing leaves to deteriorate and/or sections of the plantings to rot out. These taxa, with the exception of *Thymus pseudolanuginosus* were also adversely affected by melting snow and ice in late winter.

Lupinus perennis and *Asclepias tuberosa* were the only two taxa that died out completely in the first winter of 2009–10. In both instances, the original plants were weak when planted, and while many did not survive transplanting, the remaining plants succumbed to winter conditions. Both taxa were replanted in May 2011, and although most of the *Asclepias tuberosa* survived the replanting, none of the *Lupinus perennis* survived for more than a few weeks.

The majority of taxa grown in multiple growing depths received the same overall performance rating in each location (see Table 1). Most commonly, where taxa were grown in more than one depth but their overall ratings were not the same, plants in the deeper growing medium scored better. Among the exceptions were *Aquilegia canadensis,* which did much better in 4 inches than in 6 or 8 inches. In 4 inches, plants were adjacent to the drip line from the clerestory roof, which allowed additional moisture to splash into the growing bed during rain events. In 6 and 8 inches, plants were more exposed, especially in the 6-inch plot where the plants were located in the middle of the roof. The original plants in 8 inches eventually died out, but seedlings were established in the protected and shaded areas under or near the girders that support the solar panels. *Eriogonum umbellatum* grew better in 6 inches where they had no competition from other plants; the lack of vigor on plants in 8 inches was attributed to more competition from adjacent plants. *Sempervivum* 'Le Clair's Form' growing in 6 inches was weakened or killed by excessive water that rushed off the clerestory roof directly above the planting every time it rained.

Some taxa were not well-suited to the environment and growing conditions on the green roofs, resulting in the gradual to rapid decline of plant health and eventual death before the end of the trial. Generally, these taxa lacked vigor or remained small, and in many cases, gradually died out over successive winters. The 30 taxa that did not complete the trial are noted in Table 2. *Agastache astromontana* 'Pink Pop' and *Rudbeckia hirta* were originally planted as annuals for the dedication of the green roof in August 2009, but some plants and/or seedlings remained alive until dying out completely in 2013.

Diseases and pests were fairly insignificant in relation to the variety of taxa and the sheer number of plants on the green roof. Powdery mildew, rust, leaf spot, phomopsis blight, aphids, and lace bugs were the only problems observed. Minor powdery mildew was observed in multiple years on *Monarda fistulosa, Penstemon digitalis, P. hirsutus, Symphyotrichum novae-angliae,* and *S. oolentangiense.* Only penstemons were troubled by foliar rust, with varying infection rates noted on *Penstemon digitalis* (minor), *P. digitalis* 'Husker Red' (severe), *P. grandiflorus* (moderate), *P. grandiflorus* 'Prairie Snow' (minor), *P. hirsutus* (minor to moderate), and *P. hirsutus* 'Pygmaeus' (minor). A variety of plants were affected by bacterial or fungal leaf spotting including *Fragaria virginiana, Hosta lancifolia, Potentilla arguta, Rudbeckia fulgida,* and *Symphyotrichum novae-angliae. Juniperus horizontalis* 'Wiltonii' was periodically troubled by phomopsis tip blight *(Phomopsis juniperovora).* Spider mites were an occasional pest on *Asclepias tuberosa,* ranging

Photo by Allison Hurt

Dalea purpurea

Photo by Christine Whitacre

Fall color on *Sporobolus heterolepis* 'Tara'

from insignificant to severe infestations depending on the year. The chrysanthemum lace bug *(Corythucha marmorata)* attacks a variety of ornamental plants in the Aster family, such as chrysanthemums, asters, goldenrods, sunflowers, and black-eyed Susans, and was by far the most significant pest issue for *Ratibida pinnata, Solidago rigida, Symphyotrichum ericoides, S. novae-angliae,* and *S. oolentangiense.*

Data collection began in April 2010 with an assessment of plant losses during the first winter of 2009–10. Of the original 35,988 plants planted in 2009, approximately 25 percent died during the first winter. In subsequent years, winter losses were never as great as the first winter; winter losses in later years were more commonly associated with weakened plant health due to environmental causes such as drought rather than cold hardiness. In the spring of 2011, plants were added to several winter-decimated plots to enhance ornamental displays on the north green roof. The following taxa were supplemented due to significant plant losses sustained in winter 2009–10: *Eriogonum umbellatum* (4 and 8 inches), *Lewisia longipetala* 'Little Plum', *Linum flavum* 'Compactum' (all original plants replaced in 2011), *Origanum libanoticum* (6 and 8 inches), *O. vulgare* 'Aureum' (4 and 8 inches), *Sedum rupestre* 'Angelina', *Stachys byzantina* 'Big Ears', and *S. byzantina* 'Silver Carpet'. Snow and ice buildup was typically noted along the shaded edge of the north roof for several weeks longer in the spring than other parts of the green roofs. This phenomenon caused plants in this area to develop much later than plants growing just feet away. In addition, frost heaving and winter desiccation were consistent problems for *Armeria maritima* 'Alba', *A. maritima* 'Rubrifolia', *Aster oharai, Erigeron caespitosa, E. scopulinus, Penstemon grandiflorus,* and *P. grandiflorus* 'Prairie Snow'. In some years, *Heuchera richardsonii* and *H. micrantha* 'Palace Purple' were affected to a lesser degree.

Like any perennial garden, floral displays are important on green roofs, too. An assessment of floral traits includes flower color, flower size, bloom period, and flower production. Many taxa had exceptional floral displays, which enhanced the ornamental aspect of the green roof in spring, summer, and fall. Early bloomers such as *Viola sagittata, Antennaria dioica, Geum triflorum, Dianthus gratianopolitanus* 'Firewitch', *Phlox bifida, Tetraneuris herbacea, Tradescantia tharpii,* and cultivars of moss phlox *(Phlox subulata)* brought the green roof to life beginning in late April and early May. Summer-flowering perennials provided the longest bloom periods, from June through August. Among the best shows of the summer-flowering taxa were *Coreopsis lanceolata, Amorpha canescens, Agastache foeniculum, Bouteloua curtipendula, Calamintha nepeta* ssp. *nepeta, Dalea candida, D. purpurea, D. villosa, Koeleria glauca, K. macrantha, Penstemon digitalis, P. hirsutus,* and *P. hirsutus* 'Pygmaeus'. A variety of grasses added greatly to the late-season show along with perennials such as *Helianthus mollis, Hosta lancifolia, Hylotelephium* 'Rosy Glow', *Lespedeza capitata, Liatris ligulistylis, Salvia azurea* var. *grandiflora, Solidago rigida,* and *Solidago* 'Wichita Mountains'.

The green roof gardens were designed by OVS to be decorative and dynamic, which is especially evident in the numerous plant combinations. While not every pairing was successful, a good number of the combinations provided a succession of bloom as well as strong textural counterparts. Among the most successful plant combinations were *Solidago* 'Wichita Mountains' and *Calamagrostis brachytricha; Calamintha nepeta* ssp. *nepeta* and *Perovskia atriplicifolia; Solidago rigida, Salvia azurea* var. *grandiflora,* and *Andropogon gerardii; Phlox subulata* 'Snowflake' and 'Apple Blossom'; *Coreopsis lanceolata* and *Helianthus mollis; Artemisia ludoviciana* var.

Photo by Allison Hurt

Sporobolus heterolepis and *Monarda fistulosa*

Photo by Heidi Petersen

Viola sagittata

Photo by Christine Whitacre

Dalea purpurea

Photo by Heidi Petersen

Phlox subulata 'Snowflake' and 'Apple Blossom'

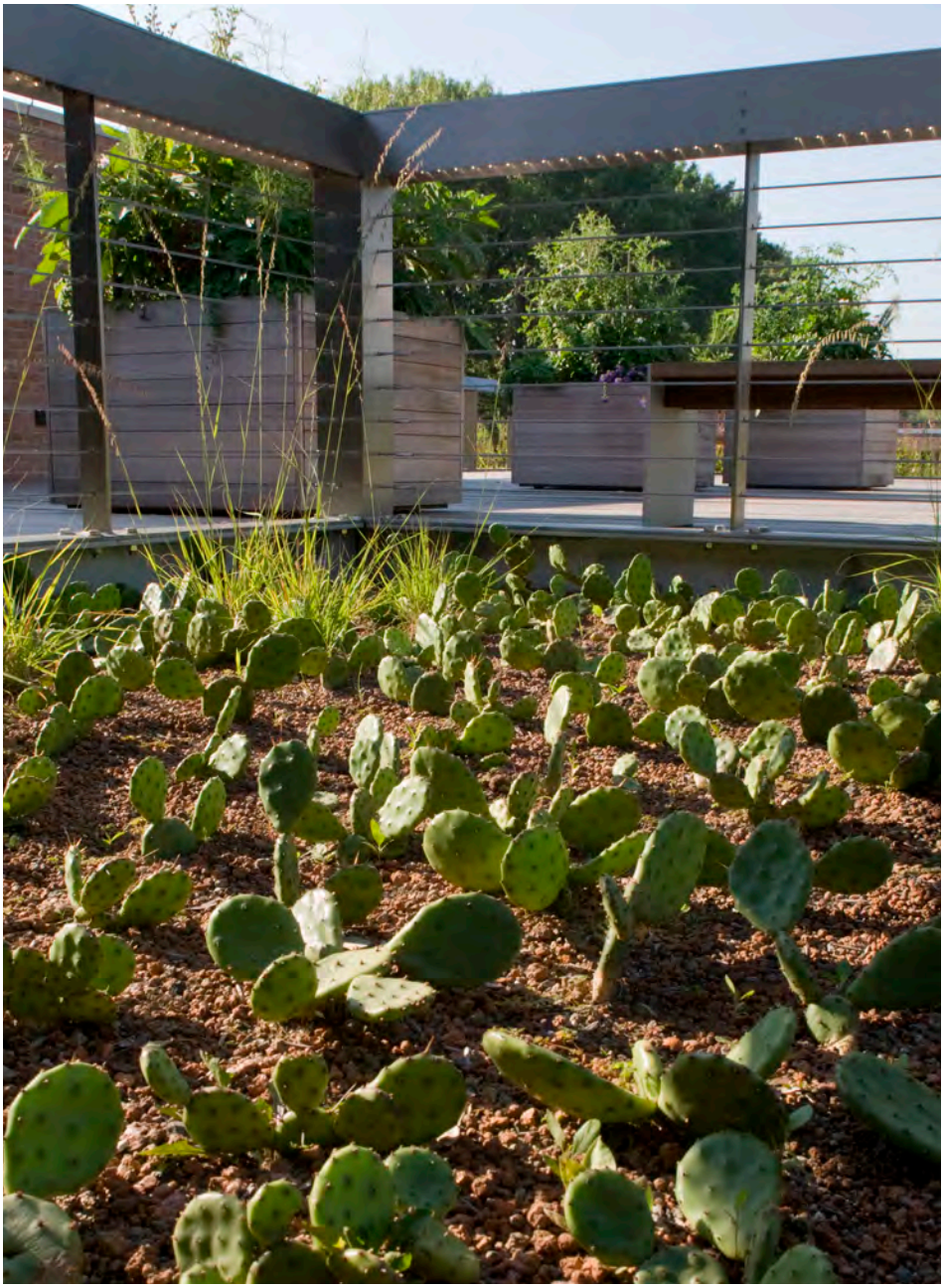
albula 'Silver King', *Origanum laevigatum* 'Herrenhausen', and *Symphyotrichum sericeum; Zizia aptera* and *Festuca amethystina* 'Superba'; and the juxtaposition of the tall and short *Penstemon hirsutus* and *P. hirsutus* 'Pygmaeus'. A serendipitous pairing of *Schizachyrium scoparium* and *Galium verum* happened when yellow bedstraw seeded among the little bluestem.

A plant's habit determines its usefulness, whether planted en masse, combined with other plants, or used as an accent. Plant habits observed on the green roofs ranged from bushy to spindly and mat-forming to spreading. Consistently strong bushy habits were observed on *Amorpha canescens, Andropogon gerardii, Calamintha nepeta* ssp. *nepeta, Ceanothus americanus, Coreopsis lanceolata, Dalea candida, D. purpurea, D. villosa, Dianthus gratianopolitanus* 'Firewitch', *Festuca amethystina* 'Superba', *Galium verum, Heuchera richardsonii, Hosta lancifolia, Hylotelephium* 'Rosy Glow', *Juniperus chinensis* var. *sargentii* 'Viridis', *J. hortizonalis* 'Wiltonii', *Koeleria glauca, K. macrantha, Nepeta racemosa* 'Walker's Low', *Penstemon digitalis, P. hirsutus, P. hirsutus* 'Pygmaeus', *Perovskia atriplicifolia, Phlox bifida, P. subulata* 'Apple Blossom', *P. subulata* 'Emerald Blue', *S. subulata* 'Snowflake', *Rhus aromatica* 'Gro-Low', *Schizachyrium scoparium, Sedum hybridum* 'Immergrünchen', *S. kamtschaticum* var. *floriferum* 'Weihenstephaner Gold', *S. spurium* 'John Creech', *Solidago rigida, S.* 'Wichita Mountains', *Sporobolus heterolepis,* and *S. heterolepis* 'Tara'. Taxa with the strongest matlike habits for use as groundcovers included *Antennaria dioica, Potentilla neumanniana, Sedum hybridum* 'Immergrünchen', and *S. kamtschaticum* 'Variegatum'. *Buchloe dactyloides* 'Legacy' was an effective groundcover, but its dense habit smothered other plants as it spread. *Origanum vulgare* 'Aureum' was also mat-forming but was a weak performer overall.

Although some taxa were healthy at all times, their habits were small, single-stemmed, or loose. Utilizing these taxa in ornamental displays would be best if the plants are closely spaced or mixed with other perennials. Taxa with loose habits included *Achillea* 'Paprika', *Amorpha nana* (plants finally became bushy in 2014), *Calamintha arkansana, Coreopsis verticillata* 'Zagreb', *Monarda punctata, Oligoneuron album, Origanum laevigatum* 'Herrenhausen', *Pycnanthemum virginianum, Ratibida pinnata, Symphyotrichum ericoides,* and *S. sericeum.* Taxa such as *Liatris ligulistylis, Symphyotrichum laeve,* and *Verbena stricta* remained mostly single-stemmed, as did many plants of *Pycnanthemum virginianum. Penstemon grandiflorus* and *P. grandiflorus* 'Prairie Snow' were typically single-stemmed but plant health was inconsistent. *Ruellia humilis* was extremely slow to develop—by 2014 some plants eventually formed small clumps.

Occasionally, plants were not able to withstand competition from adjacent plants. In these instances, health and vigor were compromised by larger, more vigorous plants that overshadowed or crowded the weaker ones. Never strong plants, *Symphyotrichum oblongifolium, S. oolentangiense,* and *S. laeve* were easily overpowered by neighboring *Andropogon gerardii, Dalea purpurea*, and *Lespedeza capitata. Artemisia stelleriana* generally lacked vigor in both 4 and 6 inches, but the closeness of *Koeleria macrantha* and *Helianthus mollis* compounded the problem. And *Symphyotrichum ericoides* 'Snow Flurry' planted among closely spaced plants of *Sporobolus heterolepis* in 8 inches simply dwindled away over several years due to the shady conditions.

Plant survival on a green roof is due in part to its ability to perpetuate itself, whether by seed or by vegetative means such as rhizomes, stolons, or suckers. Whether a plant is considered weedy or not depends on the



Opuntia humifusa

rate and degree that it spreads. None of the vegetative spreaders in the trial were considered weedy or troublesome, at least in the way they were used. In fact, a number of rhizomatous species were wide-spreading but did not form dense plantings. *Artemisia ludoviciana* var. *albula* 'Silver King' had a loose rhizomatous habit that worked well mixed with *Dianthus gratianopolitanus* 'Firewitch', where its silvery foliage created a nice contrast, but it did not out-compete the dianthus. *Helianthus mollis* also had a loose rhizomatous habit, forming a plot of single-stemmed to somewhat bushy plants; its potential to be too wide-spreading was noted. Rather than forming discrete clumps, *Monarda fistulosa* remained loosely stoloniferous. *Fragaria virginiana* displayed a robust stoloniferous habit early in the season, but the stolons were usually killed during periods of extreme heat and drought. Conversely, *Fragaria* 'Stickbolwi' never formed stolons during the trial, so its effectiveness as a groundcover was limited. *Rosa carolina* had a suckering habit that formed a thicket between the original plants, but as of 2014 the offshoots had not become problematic to nearby plantings.

Weediness is a nuisance on any green roof, but on a managed roof reseeding or spreading can be kept in check. However, on an unmanaged green roof, the proliferation of one or more species can overrun the roof, smothering or out-competing desirable plants and decreasing the diversity of the planting. Along with observing how prolifically and quickly a plant spread by seed, we also observed the pattern of dispersion or movement on the green roof. Plants were regularly monitored for seedling production to determine the degree of aggressiveness or weediness. Taxa with the highest reseeding levels included *Artemisia caudata, Calamagrostis brachytricha, Chamaecrista fasciculata* (formerly *Cassia fasciculata*), *Helianthus mollis* (also *rhizomatous*), *Hieraceum spilophaeum* 'Leopard', *Koeleria glauca, K. macrantha, Oligoneuron album, Potentilla fruticosa, Rudbeckia hirta,* and *Talinum calycinum.*

Despite heavy seed production on all of these taxa, the most aggressively weedy and/or wide-spreading of these species were *Chamaecrista fasciculata, Hieraceum spilophaeum* 'Leopard', *Koeleria glauca, K. macrantha,* and *Oligoneuron album. Koeleria glauca* and *K. macrantha* were grown on different roofs but acted the same way by filling any open space with seedlings. *Chamaecrista fasciculata* is an annual species that produced an abundance of lush seedlings each spring, most arising in the same location as the previous year but some seedlings came up several feet away. *Chamaecrista fasciculata* was unique in that its countless seedlings formed a dense mass that smothered all nearby plants, but all in all it did not spread far. *Rudbeckia hirta* is a short-lived perennial that effectively acted like an annual on the green roof. In fact, it was originally planted as a seasonal display for the opening of the green roofs in 2009 but perpetuated itself quite fruitfully during several years of the trial, dispersing widely across the green roof. *Artemisia caudata* is a biennial that produces a rosette of basal leaves the first year and a flowering stem the second year before dying out. Although quite a prolific reseeder, the seedlings did not travel far from the original plants. Reseeding levels are noted in Table 1.

Penstemon hirsutus

In a few cases, taxa planted on the north green roof were eventually observed on the south green roof, including *Dianthus carthusianorum, Leucanthemum vulgare, Hieraceum spilophaeum* 'Leopard', and *Petrorhagia saxifraga* 'Rosea'. *Talinum calycinum* was the only taxon that was observed moving from the south to the north roof. Several herbaceous taxa were discovered on the south roof, presumed to have seeded in rather than arriving with the original plants, including *Veronica spicata, Lobelia spicata,* and *Coreopsis tripteris.* In addition, a number of woody plants seeded in at various times over the course of the trial, including *Salix* spp., *Alnus hirsuta, Crataegus phaenopyrum, Acer negundo, Populus deltoides,* and *Fraxinus pennsylvanica.* Woody plants were generally not suited to the growing conditions and did not thrive.

Summary

Green roofs are a relatively new phenomenon in North America, although they have been utilized widely for a long time in Europe. Green roofs continue to grow in popularity for commercial, municipal, and residential uses alike. Green roofs provide a number of economical and environmental benefits such as reducing energy costs, managing stormwater runoff, and creating habitats for wildlife. But more and more often, green roofs are being developed for greater interaction with people, whether as pleasure spaces, urban sanctuaries, or for growing food crops. Ultimately, the success of a green roof is due to the success of the plants growing on it. Plant trials, like the one undertaken at the Chicago Botanic Garden, are crucial to increasing the knowledge about the best plants for green roof culture. Over time and with continued trialing across geographic regions, a compendium of green roof plants will be compiled.

In the five-year trial, a diverse group of 216 herbaceous and woody taxa were evaluated in the extensive to semi-intensive green roof gardens, with 78 taxa receiving top ratings for their strong performances. Many of these successful taxa grew equally well in two or more of the growing depths, an impressive feat. *Coreopsis lanceolata, Koeleria macrantha, Dalea purpurea, Sporobolus heterolepis,* and *Viola sagittata* are just a few of the strongest growers across the board. Top-rated plants consistently displayed good vigor and robust habits, superior ornamental qualities, disease resistance, heat and drought tolerance, and winter hardiness/survivability throughout the evaluation period. However, some top-rated plants such as *Koeleria macrantha* and *K. glauca* come with a caveat because they can spread generously by seed.

Plants were monitored continually to see how well they survived and thrived on the green roof. Adaptability to the growing medium and environmental conditions, in particular heat and drought, was the main criterion. Heat and drought were challenges that not all plants were able to overcome; however, the vast majority of plants survived with minimal supplemental water provided during the worst droughty periods. Although the goal of the trial was to not provide supplemental irrigation, it seemed pointless to prove that plants die without water. By the end of the trial in 2014, 14 percent of the 216 taxa planted between 2009 and 2011 had died. Of the 41,561 plants planted on both green roofs, 30,568 plants were alive in 2014.

Beyond survival, ornamental traits including floral display, habit quality, and reseed-

ing capacity were also observed. We achieved our hope of identifying a broad selection of plants with superior ornamental qualities. Top-rated taxa bloomed in spring, summer, and fall, providing beautiful floral displays on a variety of plants. The flower shows of *Dianthus gratianopolitanus* 'Firewitch', *Tetraneuris herbacea,* the cultivars of moss phlox *(Phlox subulata)*, *Coreopsis lanceolata, Amorpha canescens, Calamintha nepeta* ssp. *nepeta, Dalea villosa, Koleria macrantha, Penstemon digitalis, P. hirsutus, Helianthus mollis, Liatris ligulistylis, Salvia azurea* var. *grandiflora,* and *Solidago* 'Wichita Mountains' consistently rated highly throughout the trial.

Plants perpetuate themselves by seed or by vegetative means such as rhizomes, stolons, or suckers, and we observed all of these methods among plants on the green roof. A number of taxa spread by vegetative means but none proved to be too aggressive. On the other hand, spreading by seed was a common and sometimes troublesome occurrence on the green roof. The most vigorously reseeding taxa included *Artemisia caudata, Calamagrostis brachytricha, Chamaecrista fasciculata, Helianthus mollis, Hieracium spilophaeum* 'Leopard', *Koeleria glauca, K. macrantha, Oligoneuron album, Potentilla fruticosa, Rudbeckia hirta,* and *Talinum calycinum.* By all measures, *Chamaecrista fasciculata* (formerly *Cassia fasciculata*) was the most prolific reseeder, dropping so much seed that the resulting seedlings formed an impenetrable mass that filled all nearby open ground and enveloped other plants.

Photo by Heidi Petersen

Aquilegia canadensis

Perovskia atriplicifolia

The replication of taxa in multiple locations was something we achieved 36 percent of the time in our original trial. Going forward, we plan to increase that rate so that the majority of plants are growing in two or three of the medium depths. We believe this is especially important for taxa that have not been previously grown on a green roof. Beginning in 2012, the third year of the original trial, we added 46 taxa to the green roof. These taxa will be evaluated for five years to ensure they are fully adaptable to green roof culture before recommendations are made. And in 2015, new taxa will be incorporated into the continuing trials as we work toward compiling an extensive list of the best plants for green roofs.

References

Dunnett, N. and N. Kingsbury. 2004. ***Planting Green Roofs and Living Walls.*** Portland, OR: Timber Press.

Snodgrass, E.C. and L. McIntryre. 2010. ***The Green Roof Manual.*** Portland, OR: Timber Press.

Snodgrass, E.C. and L.L. Snodgrass. 2006. ***Green Roof Plants.*** Portland, OR: Timber Press.

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Table 1: Performance Ratings and Plant Traits Observed on Chicago Botanic Garden Green Roof

Rating	Roof/Depth	Plant Name	Flower Color	Flower Size	Bloom Period	Flower Production	Reseeding[1]	Height	Width	Heat/Drought[2]
★★	North 8 in.	*Achillea* 'Paprika'	red	2½ in. wide	early Jun-early Sep	good	none	8 in.	32 in.	minor
★★★	North 6 in.	*Agastache astromontana* 'Pink Pop'	pinkish purple	4 in. long	early Jul-early Sep	excellent	low	9-21 in.	4-15 in.	minor
★★★★	North 6 in.	*Agastache foeniculum*	lavender	3½ in. long	late Jun-mid Sep	excellent	moderate	17 in.	18 in.	minor
★★★	North 8 in.	*Agastache foeniculum*	lavender	3½ in. long	late Jun-mid Sep	fair	moderate	24 in.	10 in.	minor
★★★	North 4 in.	*Alchemilla mollis* 'Auslese'	yellow	¾ in. wide	early Jun-early Jul	good	none	6 in.	7 in.	minor
★★★	South 6 in.	*Allium cernuum*	lavender	2 in. wide	late Jul-mid Sep	fair	none	28 in.	12 in.	moderate
★★★★	South 8 in.	*Allium cernuum*	lavender	2 in. wide	late Jul-mid Sep	good	none	36 in.	15 in.	moderate
★★★★	South 6 in.	*Amorpha canescens*	purple	6 in. long	early Jul-late Jul	excellent	none	28 in.	18 in.	none
★★★★	South 8 in.	*Amorpha canescens*	purple	6 in. long	early Jul-late Jul	excellent	none	33 in.	18 in.	none
★★★	South 6 in.	*Amorpha nana*	n/a	n/a	did not flower	n/a	none	17 in.	16 in.	none
★★★	South 8 in.	*Amorpha nana*	n/a	n/a	did not flower	n/a	none	15 in.	24 in.	none
★★★★	South 4 in.	*Andropogon gerardii*	purple	n/a	late Aug-Oct	excellent	low-moderate	59 in.	22 in.	moderate
★★★★	South 6 in.	*Andropogon gerardii*	purple	n/a	late Aug-Oct	excellent	low-moderate	74 in.	28 in.	moderate
★★★★	South 8 in.	*Andropogon gerardii*	purple	n/a	late Aug-Oct	excellent	low-moderate	100 in.	30 in.	moderate
★★	South 6 in.	*Anemone caroliniana*	white	1¾ in. wide	early Jun-late Jul	fair	low	7 in.	10 in.	minor
★★★	South 4 in.	*Anemone cylindrica*	white	¾ in. wide	late Jun-mid Jul	fair	none	22 in.	10 in.	none
★★★	South 6 in.	*Anemone cylindrica*	white	⅞ in. wide	mid Jun-early Jul	fair	none	19 in.	9 in.	none
★★★	South 8 in.	*Anemone cylindrica*	white	⅞ in. wide	mid Jun-mid Jul	fair	none	28 in.	14 in.	none
★★★★★	North 4 in.	*Antennaria dioica*	white	¼ in. wide	late May-early Jul	excellent	none	6 in.	24 in.	none
★★★★	South 4 in.	*Aquilegia canadensis*	red, yellow	1 in. wide	mid May-mid Jul	excellent	moderate	31-45 in.	14-21 in.	moderate
★★	South 6 in.	*Aquilegia canadensis*	red, yellow	1 in. wide	mid May-mid Jun	fair	none	20 in.	8 in.	moderate
★★★★	South 8 in.	*Aquilegia canadensis*	red, yellow	1½ wide	mid May-late Jun	good	moderate	24 in.	16 in.	moderate
★★	South 4 in.	A*rctostaphylos uva-ursi*	n/a	n/a	did not flower	n/a	n/a	3 in.	15 in.	minor
★★	South 6 in.	*Arctostaphylos uva-ursi*	n/a	n/a	did not flower	n/a	n/a	4 in.	9 in.	minor
★★★	South 8 in.	*Arctostaphylos uva-ursi*	n/a	n/a	did not flower	n/a	n/a	8 in.	12 in.	minor
★★	North 4 in.	*Armeria maritima* 'Alba'	white	1 in. wide	early May-mid Jun	fair	none	3-10 in.	7 in.	none
★★★★	North 6 in.	*Armeria maritima* 'Alba'	white	1 in. wide	early May-mid Jun	excellent	none	4-11 in.	7-10 in.	none
★★	North 6 in.	*Armeria maritima* 'Rubrifolia'	deep purple-pink	1 in. wide	mid May-late Jun	poor	none	2-7 in.	5-7 in.	moderate
★★★★	South 4 in.	*Artemisia caudata*	yellow-green	⅛ in. wide	early Aug-mid Sep	excellent	heavy	44 in.	9 in.	minor
★★★★	South 6 in.	*Artemisia caudata*	yellow-green	⅛ in. wide	early Aug-mid Sep	excellent	heavy	36 in.	7 in.	minor
★★	South 4 in.	*Artemisia frigida*	yellow	n/a	early Jul-late Jul	poor	none	11 in.	14 in.	minor
★★	South 6 in.	*Artemisia frigida*	yellow	n/a	early Jul-late Jul	poor	none	10 in.	23 in.	minor
★★	South 8 in.	*Artemisia frigida*	yellow	n/a	early Jul-late Jul	poor	none	13 in.	18 in.	minor
★★★★	North 8 in.	*Artemisia ludoviciana* var. *albula* 'Silver King'	yellow-gray	⅛ in. wide	mid Sep-early Oct	good	none	17 in.	spreading	none
★★★	South 8 in.	*Artemisia schmidtiana* 'Silver Mound'	silver	n/a	mid Aug-mid Sep	good	none	10 in.	24 in.	none
★★	South 4 in.	*Artemisia stelleriana*	silvery green	¼ in. wide	mid Jun-early Jul	fair	none	14 in.	19 in.	minor
★★★	South 6 in.	*Artemisia stelleriana*	silvery green	¼ in. wide	early Jun-early Jul	fair	none	17 in.	27-36 in.	minor
★★	South 4 in.	*Asclepias tuberosa*	orange	2½ in. wide	late Jun-late Aug	fair	none	12 in.	10 in.	moderate
★★	South 6 in.	*Asclepias tuberosa*	orange	2½ in. wide	late Jun-late Jul	fair	none	13 in.	11 in,	moderate
★★★	South 8 in.	*Asclepias tuberosa*	orange	2½ in. wide	late Jun-mid Aug	fair	none	21 in.	9 in.	moderate
★★★	North 4 in.	*Aster alpinus* var. *albus*	white	2 in. wide	early Jun-late Jun	fair	none	10 in.	7 in.	minor
★★★★	North 6 in.	*Aster alpinus* var. *albus*	white	2 in. wide	early Jun-late Jun	excellent	none	3 in.	6 in.	minor
★★★	North 4 in.	*Aster oharai*	lavender-blue	1½ in. wide	early Sep-mid Oct	fair	none	5 in.	6 in.	none
★★★★	South 8 in.	*Baptisia alba* var. *alba*	white	1 in. wide	early Jun-early Jul	fair	none	34 in.	46 in.	severe
★★★	South 4 in.	*Bouteloua curtipendula*	purple	11 in. long	mid Jul-late Aug	excellent	low	37 in.	24 in.	minor
★★★★	South 6 in.	*Bouteloua curtipendula*	purple	11 in. long	late Jul-early Sep	excellent	low	44 in.	33 in.	minor
★★★★	South 8 in.	*Bouteloua curtipendula*	burgundy	12 in. long	mid Jul-early Sep	excellent	moderate	44 in.	36 in.	minor

★★★	South 4 in.	*Bouteloua gracilis*	red, green	1 in. long	Aug	poor	none	18 in.	8 in.	none
★★★	South 6 in.	*Bouteloua gracilis*	red, green	1 in. long	Aug	poor	none	15 in.	9 in.	none
★★★	South 8 in.	*Bouteloua gracilis*	red, green	1½ in. long	Aug	poor	none	24 in.	10 in.	none
★★★★	North 4 in.	*Buchloe dactyloides* 'Legacy'	n/a	n/a	did not flower	n/a	none	3 in.	spreading	moderate
★★★★	North 6 in.	*Buchloe dactyloides* 'Legacy'	n/a	n/a	did not flower	n/a	none	3 in.	spreading	moderate
★★	North 8 in.	*Buddleja davidii* 'Blue Chip'	light purple	5 in. long	early Aug-early Oct	excellent	none	10 in.	12 in.	minor
★★★★	North 8 in.	*Calamagrostis brachytricha*	green, purple	11 in. long	early Sep-early Oct	excellent	heavy	52 in.	28 in.	minor
★★★	South 4 in.	*Calamintha arkansana*	light purple	¼ in. wide	early Jul-mid Aug	excellent	none	9 in.	10 in.	moderate
★★★	South 6 in.	*Calamintha arkansana*	light purple	¼ in. wide	early Jul-mid Aug	excellent	none	12 in.	6 in.	moderate
★★★★★	North 6 in.	*Calamintha nepeta* ssp. *nepeta*	white	¼ in. wide	mid Jul-early Nov	excellent	none	17 in.	17 in.	minor
★★★★★	North 8 in.	*Calamintha nepeta* ssp. *nepeta*	white	¼ in. wide	mid Jul-early Nov	excellent	none	25 in.	32 in.	minor
★★	South 8 in.	*Callirhoe involucrata*	magenta	1¼ in. wide	mid Jun-mid Jul	fair	none	4 in.	18 in.	moderate
★★★★	South 6 in.	*Campanula rotundifolia*	light purple	1 in. wide	mid May-early Aug	excellent	none	18 in.	6 in.	minor
★★★	North 6 in.	*Campanula trachelium*	purple	1 in. wide	early Jul-mid Nov	good	none	25 in.	14 in.	minor
★★	South 8 in.	*Campanulastrum americanum*	lavender-blue	1 in. wide	early Jul-mid Aug	poor	low	32 in.	4 in.	moderate
★★★	South 4 in.	*Carex radiata*	light green	1 in. long	Jun-Jul	fair	none	10 in.	13 in.	minor
★★★	South 6 in.	*Carex radiata*	light green	1 in. long	Jun-Jul	fair	none	10 in.	10 in.	minor
★★★	South 8 in.	*Carex radiata*	light green	1 in. long	Jun-Jul	fair	none	12 in.	11 in.	minor
★★★★	South 8 in.	*Ceanothus americanus*	white	2 in. long	early Jul-early Aug	excellent	none	46 in.	48 in.	none
★★★	North 6 in.	*Cerastium tomentosum*	white	¾ in. wide	late May-late Jun	good	none	4-6 in.	11-15 in.	minor
★★★	South 6 in.	*Chamaecrista fasciculata*	yellow	1 in. wide	late Jul-mid Sep	excellent	heavy	18 in.	23 in.	severe
★★★	South 8 in.	*Chamaecrista fasciculata*	yellow	1 in. wide	late Jul-mid Sep	excellent	heavy	26 in.	5 in.	severe
★★★★	South 4 in.	*Coreopsis lanceolata*	golden-yellow	1¾ in. wide	late May-late Jun	good	low	14 in.	13 in.	moderate
★★★★	South 6 in.	*Coreopsis lanceolata*	golden-yellow	2¼ in. wide	early Jun-early Jul	excellent	low	13 in.	15 in.	moderate
★★★★	South 8 in.	*Coreopsis lanceolata*	golden-yellow	2¼ in. wide	early Jun-early Jul	excellent	low	14 in.	11 in.	minor
★★★★	North 4 in.	*Coreopsis verticillata* 'Zagreb'	golden-yellow	1½ in. wide	early Jun-late Sep	excellent	none	11 in.	14 in.	none
★★★★	South 4 in.	*Dalea candida*	white	2 in. long	early Jul-early Aug	excellent	low	34 in.	26 in.	moderate
★★★★	South 8 in.	*Dalea candida*	white	2¼ in. long	late Jun-early Aug	excellent	low	25 in.	16 in.	moderate
★★★★	South 4 in.	*Dalea purpurea*	purple	1½ in. long	early Jul-early Aug	excellent	moderate	28 in.	21 in.	minor
★★★★	South 6 in.	*Dalea purpurea*	purple	1¾ in. long	early Jul-early Aug	excellent	moderate	24 in.	10 in.	minor
★★★★	South 8 in.	*Dalea purpurea*	purple	2 in. long	late Jun-early Aug	excellent	moderate	27 in.	14 in.	minor
★★★★	South 6 in.	*Dalea villosa*	magenta	1½ in. long	Jul	excellent	none	22 in.	14 in.	none
★★★	North 4 in.	*Dianthus carthusianorum*	magenta	⅞ in. wide	early Jun-late Jul	good	low	10 in.	6 in.	minor
★★★★	North 4 in.	*Dianthus gratianopolitanus* 'Firewitch'	magenta-pink	1 in. wide	late May-late Jun	excellent	low	7 in.	12 in.	minor
★★★★	North 8 in.	*Dianthus gratianopolitanus* 'Firewitch'	magenta-pink	1 in. wide	late May-early Jul	excellent	low	7 in.	11 in.	minor
★★★	South 8 in.	*Echinacea pallida*	light purple-pink	3 in. wide	mid Jun-late Jul	excellent	none	28 in.	6 in.	moderate
★★★	South 6 in.	*Echinacea purpurea*	purple-pink	2½ in. wide	mid Jul-early Sep	fair	none	19 in.	10 in.	moderate
★★★	South 6 in.	*Eragrostis spectabilis*	purple	5 in. wide	mid Sep-mid Oct	fair	none	15 in.	15 in.	minor
★★★	South 8 in.	*Eragrostis spectabilis*	purple	5 in. wide	mid Sep-mid Oct	fair	none	25 in.	24 in.	minor
★★	South 4 in.	*Erigeron caespitosa*	lavender	1 in. wide	late May-early Jul	poor	none	4 in.	8 in.	moderate
★★	South 8 in.	*Erigeron caespitosa*	lavender	1 in. wide	late May-early Jul	good	none	5 in.	8 in.	moderate
★★	North 4 in.	*Erigeron scopulinus*	lavender	1¼ in. wide	mid Jun-late Jul	poor	none	5 in.	6 in.	none
★★★	North 4 in.	*Eriogonum umbellatum*	yellow	¾ in. wide	late May-mid Jul	good	none	4-15 in.	6-10 in.	moderate
★★	North 8 in.	*Eriogonum umbellatum*	n/a	n/a	did not flower	n/a	n/a	2-5 in.	4-7 in.	none
★★★	South 4 in.	*Eryngium yuccifolium*	white	¾ in. wide	early Jul-early Aug	poor	none	22 in.	11 in.	minor
★★★	South 6 in.	*Eryngium yuccifolium*	white	¾ in. wide	Aug	poor	none	9 in.	14 in.	minor
★★★★	North 6 in.	*Festuca amethystina* 'Superba'	tan	3 in. wide	early Jun-early Jul	excellent	none	19 in.	15 in.	moderate
★★	North 4 in.	*Festuca glauca*	tan	n/a	Jun	poor	none	14 in.	8 in.	minor
★★	North 6 in.	*Festuca glauca*	tan	n/a	Jun	poor	none	7 in.	10 in.	minor
★★★	North 4 in.	*Fragaria* 'Stickbolwi'	red-pink	¾ in. wide	early May-late Aug	fair	none	4 in.	9 in.	moderate

★★★	South 4 in.	*Fragaria virginiana*	white	¾ in. wide	mid May-early Jun	fair	low	5 in.	12 in.	moderate -severe
★★★★	South 6 in.	*Fragaria virginiana*	white	1 in.	mid May-early Jun	fair	low	5 in.	10 in.	moderate -severe
★★★★	North 4 in.	*Galium verum*	yellow	7 in. long	late Jun--late Sep	excellent	moderate	31 in.	13 in.	none
★★★★	North 8 in.	*Galium verum*	yellow	9 in. long	mid Jun-mid Sep	excellent	moderate	33 in.	22 in.	none
★★★	North 4 in.	*Geranium ×cantabrigiense* 'Biokovo'	pale pink	1⅛ in. wide	mid Jun-mid Jul	good	none	6 in.	15 in.	moderate
★★★	South 4 in.	*Geum triflorum*	pink-red	1½ in. wide	early May-early Jun	fair	moderate	11 in.	10 in.	severe
★★★★	South 6 in.	*Geum triflorum*	pink-red	1½ in. wide	early May-early Jun	excellent	moderate	12 in.	15 in.	severe
★★★	North 4 in.	*Gypsophila repens* 'Rosea'	light pink	⅜ in. wide	late May-late Jul	good	low	4 in.	16 in.	moderate
★★★★	North 8 in.	*Helianthus mollis*	golden-yellow	3 in. wide	early Aug-late Sep	excellent	moderate-heavy	33 in.	28 in.	none
★★★	North 4 in.	*Heuchera micrantha* 'Palace Purple'	white	¼ in. wide	mid Jul-late Aug	fair	none	15 in.	21 in.	minor
★★★	North 6 in.	*Heuchera micrantha* 'Palace Purple'	white	¼ in. wide	mid Jul-late Aug	fair	none	15 in.	14 in.	minor
★★★★	North 8 in.	*Heuchera richardsonii*	green	15 in. long	late May-early Jul	excellent	none	42 in.	15 in.	moderate
★★★★	North 4 in.	*Hieracium spilophaeum* 'Leopard'	yellow	1 in. wide	late May-late Sep	fair	moderate	16 in.	8 in.	none
★★★★	North 8 in.	*Hieracium spilophaeum* 'Leopard'	yellow	1¼ in. wide	mid May-late Sep	fair	heavy	19 in.	9 in.	none
★★★	North 4 in.	*Hosta* 'Cracker Crumbs'	light purple	2 in. long	early Jul-late Aug	excellent	none	4 in.	8 in.	moderate
★★★★	North 6 in.	*Hosta lancifolia*	light purple	2½ in. long	late Aug-Oct	excellent	none	35 in.	18 in.	minor
★★★★	North 4 in.	*Hylotelephium* 'Rosy Glow'	purple	⅜ in. wide	Sep	good	none	7 in.	15 in.	none
★★★★	North 6 in.	*Hylotelephium* 'Rosy Glow'	purple	⅜ in. wide	Sep	excellent	none	6 in.	10 in.	none
★★★★	North 8 in.	*Hylotelephium* 'Rosy Glow'	purple	⅜ in. wide	Sep	excellent	none	8 in.	10 in.	none
★★	North 4 in.	*Hylotelephium sieboldii*	n/a	n/a	did not flower	n/a	n/a	5 in.	14 in.	none
★★	North 6 in.	*Hylotelephium sieboldii*	n/a	n/a	did not flower	n/a	n/a	5 in.	16 in.	none
★★	North 8 in.	*Hylotelephium spectabile* 'Neon'	pink	½ in. wide	Sep	fair	none	13 in.	18 in.	none
★★★	North 6 in.	*Iris tectorum*	lilac	4 in. wide	late May-mid Jun	fair	none	13 in.	18 in.	minor
★★★★★	North 8 in.	*Juniperus chinensis* var. *sargentii* 'Viridis'	n/a	n/a	n/a	n/a	none	5 in.	36 in.	none
★★★★	North 8 in.	*Juniperus horizontalis* 'Wiltonii'	n/a	n/a	n/a	n/a	none	7 in.	46 in.	none
★★★★	North 6 in.	*Koeleria glauca*	tan	3 in. long	early Jun-late Jun	excellent	heavy	26 in.	10 in.	minor
★★★★	South 4 in.	*Koeleria macrantha*	light green	4 in. long	Jun-Jul	good	moderate	24 in.	12 in.	minor
★★★★	South 6 in.	*Koeleria macrantha*	light green	4 in. long	Jun-Jul	excellent	moderate-heavy	28 in.	15 in.	minor
★★★★	South 8 in.	*Koeleria macrantha*	light green	4 in. long	Jun-Jul	excellent	moderate	24 in.	15 in.	minor
★★	North 6 in.	*Lavandula angustifolia* 'Hidcote'	lavender	2½ in. long	early Jul-late Oct	fair	none	9 in.	12 in.	none
★★★	North 8 in.	*Lavandula angustifolia* 'Hidcote'	lavender	2½ in. long	early Jul-late Oct	fair	none	19 in.	12 in.	none
★★	South 4 in.	*Lespedeza capitata*	white	6 in. long	mid Aug-late Sep	good	low	30 in.	18 in.	minor
★★★★	South 8 in.	*Lespedeza capitata*	white	6 in. long	early Aug-late Sep	good	low	42 in.	20 in.	minor
★★★	North 4 in.	*Leucanthemum vulgare*	white, yellow	1¾ in. wide	late May-early Jul	excellent	moderate	15 in.	10 in.	moderate
★★★	North 8 in.	*Leucanthemum vulgare*	white, yellow	1¾ in. wide	early Jun-mid Jul	excellent	moderate	15 in.	8 in.	moderate
★★	North 4 in.	*Lewisia longipetala* 'Little Plum'	pink	1½ in. wide	mid May-mid Jul	good	none	1¼ in.	2 in.	moderate
★★★	South 4 in.	*Liatris cylindracea*	mauve	1 in. wide	early Aug-mid Sep	good	none	12 in.	12 in.	minor
★★★★	South 6 in.	*Liatris cylindracea*	mauve	1 in. wide	early Aug-mid Sep	good	none	16 in.	16 in.	minor
★★★★	South 8 in.	*Liatris cylindracea*	mauve	1 in. wide	early Aug-mid Sep	good	none	23 in.	9 in.	minor
★★★★	South 8 in.	*Liatris ligulistylis*	light purple	22 in. long	early Aug-early Oct	excellent	low	33 in.	10 in.	minor
★★	North 4 in.	*Linum flavum* 'Compactum'	yellow	1 in. wide	mid Jun-early Aug	excellent	none	8-12 in.	5-12 in.	none
★	South 6 in.	*Lupinus perennis*	n/a	n/a	did not flower	n/a	n/a	n/a	n/a	severe
★★★★	South 6 in.	*Monarda fistulosa*	light purple	2 in. wide	early Jul-early Sep	excellent	low	29 in.	17 in.	minor
★★★	South 4 in.	*Monarda punctata*	light yellow	½ in. long	late Jul-mid Aug	good	low	10 in.	7 in.	minor
★★★	South 6 in.	*Monarda punctata*	light yellow	½ in. long	late Jul-late Aug	good	low	15 in.	13 in.	minor
★★★	South 8 in.	*Monarda punctata*	light yellow	½ in. long	late Jul-late Aug	good	low	14 in.	10 in.	minor
★★★★	North 8 in.	*Nepeta racemosa* 'Walker's Low'	lavender-blue	9 in. long	early Jun-late Oct	good	none	20 in.	30 in.	minor

★★★	North 4 in.	*Oenothera fruticosa* 'Fireworks'	yellow	1¾ in. wide	mid Jun-late Jul	fair	none	18-24 in.	15-18 in.	moderate
★★★	North 8 in.	*Oenothera fruticosa* 'Fireworks'	yellow	1¾ in. wide	mid Jun-mid Jul	good	none	18-24 in.	10-17 in.	moderate
★★	South 4 in.	*Oenothera macrocarpa*	yellow	3 in. wide	early Jun-early Jul	fair	none	3 in.	10 in.	moderate
★★	South 6 in.	*Oenothera macrocarpa*	yellow	3 in. wide	early Jun-early Jul	good	none	3 in.	10 in.	moderate
★★★	South 8 in.	*Oenothera macrocarpa*	yellow	3½ in. wide	mid Jun-early Aug	good	none	4 in.	13 in.	moderate
★★★★	South 8 in.	*Oligoneuron album*	white	¾ in. wide	mid Jun-mid Sep	excellent	heavy	12 in.	20 in.	minor
★★★	South 4 in.	*Opuntia humifusa*	yellow	3 in. wide	late Jun-mid Jul	poor	none	4 in.	12 in.	none
★★★	North 8 in.	*Origanum laevigatum* 'Herrenhausen'	light purple	2 in. wide	mid Jul-early Sep	excellent	moderate	27 in.	36 in.	minor
★★	North 6 in.	*Origanum libanoticum*	light purple	½ in. wide	late Jun-late Aug	good	none	10 in.	19 in.	none
★★	North 8 in.	*Origanum libanoticum*	light purple	½ in. wide	mid Jul-mid Aug	fair	none	8-11 in.	10-16 in.	none
★★	North 4 in.	*Origanum vulgare* 'Aureum'	white	⅜ in. wide	late Jun-early Aug	poor	none	7-13 in.	11-17 in.	moderate
★★	North 8 in.	*Origanum vulgare* 'Aureum'	white	⅜ in. wide	mid Jul-mid Aug	poor	none	1 in.	10 in.	moderate
★★	North 8 in.	*Pachysandra procumbens*	n/a	n/a	did not flower	n/a	none	4 in.	4 in.	none
★★★	South 4 in.	*Penstemon digitalis*	white	1¼ in. long	early Jun-mid Jul	good	moderate	18 in.	12 in.	moderate
★★★★	South 6 in.	*Penstemon digitalis*	white	1¼ in. long	early Jun-mid Jul	excellent	moderate	28 in.	21 in.	moderate
★★★★	South 8 in.	Penstemon digitalis	white	1¼ in. long	early Jun-mid Jul	excellent	low	27 in.	24 in.	minor
★★★	North 8 in.	*Penstemon digitalis* 'Husker Red'	white	6 in. long	mid Jun-mid Jul	excellent	none	15 in.	7 in.	moderate
★	South 4 in.	*Penstemon grandiflorus*	light purple	1¼ in. long	early Jun-late Jun	fair	none	7 in.	4 in.	severe
★★	South 6 in.	*Penstemon grandiflorus*	light lavender	2 in. long	early Jun-late Jun	good	low	12 in.	7 in.	moderate
★★	South 8 in.	*Penstemon grandiflorus*	light purple	1 in. long	early Jun-early Jul	good	low	24 in.	7 in.	minor
★★	North 6 in.	*Penstemon grandiflorus* 'Prairie Snow'	white	1¾ in. long	early Jun-late Jun	excellent	none	18 in.	6 in.	none
★★★★	North 6 in.	*Penstemon hirsutus*	light purple	1 in. long	early Jun-early Jul	excellent	moderate	11 in.	18 in.	minor
★★★★	North 8 in.	*Penstemon hirsutus*	light purple	1 in. long	early Jun-early Jul	excellent	moderate	17 in.	17 in.	minor
★★★★	North 6 in.	*Penstemon hirsutus* 'Pygmaeus'	light purple	1 in. long	early Jun-early Jul	excellent	low	6 in.	9 in.	minor
★★★★	North 8 in.	*Penstemon hirsutus* 'Pygmaeus'	light purple	1 in. long	early Jun-early Jul	excellent	low	9 in.	8 in.	minor
★★	North 8 in.	*Penstemon ×mexicali* 'Red Rocks'	magenta	1¼ in. long	late Jun-late Sep	poor	none	15 in.	20 in.	moderate
★★★★	North 8 in.	*Perovskia atriplicifolia*	lavender	18 in. long	early Jul-late Oct	good	none	36 in.	26 in.	minor
★★★★	North 4 in.	*Petrorhagia saxifraga* 'Rosea'	pink	¼ in. wide	mid Jun-early Sep	excellent	moderate	10 in.	16 in.	moderate
★★★★	South 8 in.	*Phlox bifida*	light blue	1 in. wide	early May-early Jun	excellent	low	7 in.	12 in.	minor
★★★★★	North 6 in.	*Phlox subulata* 'Apple Blossom'	light pink	¾ in. wide	early May-early Jun	excellent	none	3 in.	13 in.	minor
★★★★★	North 4 in.	*Phlox subulata* 'Emerald Blue'	lavender	1 in. wide	early May-early Jun	excellent	none	6 in.	20 in.	minor
★★★★★	North 4 in.	*Phlox subulata* 'Snowflake'	white	⅝ in. wide	early May-early Jun	excellent	none	3 in.	12 in.	minor
★★★★★	North 6 in.	*Phlox subulata* 'Snowflake'	white	⅝ in. wide	early May-early Jun	excellent	none	4 in.	13 in.	minor
★★★	South 4 in.	*Potentilla arguta*	white	1 in. wide	early Jul-late Jul	fair	none	34 in.	13 in.	moderate
★★★	South 6 in.	*Potentilla arguta*	white	1 in. wide	early Jul-early Aug	fair	none	37 in.	15 in.	minor
★★★★	South 8 in.	*Potentilla arguta*	white	1 in. wide	early Jul-late Jul	excellent	none	35 in.	20 in.	none
★★★★	South 8 in.	*Potentilla fruticosa*	yellow	1 in. wide	early Jun-late Sep	excellent	moderate-heavy	19 in.	19 in.	moderate
★★★	South 6 in.	*Potentilla neumanniana*	yellow	½ in. wide	early May-early Jun	good	none	1 in.	16 in.	moderate
★★	North 6 in.	*Prunella grandiflora*	purple	¼ in. wide	late Jun-mid-Aug	poor	low	4 in.	10 in.	moderate
★★★	South 6 in.	*Pulsatilla patens*	pale lavender	2 in. wide	mid Apr-mid May	fair	low	4 in.	10 in.	moderate
★★★	South 8 in.	*Pulsatilla patens*	pale lavender	2¼ in. wide	mid Apr-mid May	fair	low	5 in.	24 in.	moderate
★★★	North 4 in.	*Pulsatilla vulgaris*	purple	2 in. wide	mid Apr-early Jun	good	low	14 in.	13 in.	minor
★★★★	North 6 in.	*Pulsatilla vulgaris*	purple	2 in. wide	mid Apr-early Jun	good	moderate	14 in.	11 in.	minor
★★★	North 4 in.	*Pulsatilla vulgaris* 'Alba'	white	1¾ in. wide	late Apr-late May	excellent	none	9 in.	18 in.	moderate
★★★★	South 8 in.	*Pycnanthemum virginianum*	white	¼ in. long	mid Jul-late Sep	good	low	22 in.	13 in.	minor
★★★	South 6 in.	*Ratibida pinnata*	yellow	2¼ in. wide	late Jul-late Sep	fair	none	31 in.	15 in.	minor
★★★★★	North 8 in.	*Rhus aromatica* 'Gro-Low'	yellow	½ in. wide	early May-mid Jun	excellent	none	26 in.	34 in.	none
★★★★	North 8 in.	*Rosa carolina*	light pink	2 in. wide	mid Jun-early Jul	good	none	30 in.	48 in.	none
★★	South 4 in.	*Rudbeckia fulgida*	golden-yellow	2 in. wide	early Aug-late Sep	fair	none	14 in.	9 in.	severe

★★	South 6 in.	*Rudbeckia fulgida*	golden-yellow	2½ in. wide	early Aug-late Sep	good	none	18 in.	10 in.	severe
★★	South 8 in.	*Rudbeckia fulgida*	golden-yellow	2½ in. wide	early Aug-late Sep	good	none	18 in.	10 in.	severe
★★	South 8 in.	*Rudbeckia hirta*	golden-yellow	2½ in. wide	mid Jun-late Sep	excellent	heavy	20 in.	12 in.	severe
★★★	South 4 in.	*Ruellia humilis*	lavender	1¾ in. wide	early Jul-mid Aug	fair	none	6 in.	6 in.	minor
★★	North 6 in.	*Salvia argentea*	n/a	n/a	did not flower	n/a	none	3 in.	6 in.	none
★★★	South 4 in.	*Salvia azurea* var. *grandiflora*	blue	⅝ in. wide	early Sep-late Oct	good	none	39 in.	16 in.	none
★★★★	South 6 in.	*Salvia azurea* var. *grandiflora*	blue	⅝ in. wide	early Sep-late Oct	good	none	54 in.	15 in.	none
★★★★	South 8 in.	*Salvia azurea* var. *grandiflora*	blue	⅝ in. wide	early Sep-late Oct	good	none	61 in.	14 in.	none
★★★	North 6 in.	*Salvia officinalis*	purple	1 in. long	early Jun-mid Jul	good	none	10 in.	16 in.	minor
★★★	North 8 in.	*Salvia officinalis*	purple	1 in. long	early Jun-mid Jul	good	none	14 in.	14 in.	minor
★★	North 4 in.	*Salvia pratensis* 'Swan Lake'	white	8 in. long	early Jun-late Jun	poor	none	12 in.	12 in.	minor
★★★	North 6 in.	*Salvia pratensis* 'Swan Lake'	white	8 in. long	late May-late Jun	fair	none	9 in.	16 in.	minor
★★	North 8 in.	*Salvia pratensis* 'Swan Lake'	white	8 in. long	late May-late Jun	poor	none	15 in.	12 in.	minor
★★★	North 4 in.	*Salvia ×sylvestris* 'East Friesland'	purple	4 in. long	late May-late Jun	good	none	8 in.	8 in.	minor
★★★★	North 6 in.	*Salvia ×sylvestris* 'East Friesland'	purple	7 in. long	early Jun-mid Jul	good	none	10 in.	10 in.	minor
★★★	North 6 in.	*Saponaria ocymoides*	pink	½ in. wide	late May-late Jun	excellent	none	10 in.	25 in.	minor
★★★★	North 8 in.	*Schizachyrium scoparium*	purple-red	9½ in. long	early Aug-early Sep	excellent	moderate	41 in.	20 in.	minor
★★★★	North 6 in.	*Scilla numidica*	light purple	½ in. wide	mid Sep-early Oct	good	none	7 in.	9 in.	none
★★	North 8 in.	*Scutellaria alpina*	purple	1 in. long	mid Jun-mid Jul	poor	none	9 in	13 in.	moderate
★★★	South 4 in.	*Scutellaria resinosa*	purple	1 in. long	mid Jun-early Aug	good	moderate	12 in.	12 in.	minor
★★★	South 6 in.	*Scutellaria resinosa*	purple	1 in. long	mid Jun-early Aug	good	moderate	10 in.	9 in.	minor
★★★	South 8 in.	*Scutellaria resinosa*	purple	1 in. long	mid Jun-early Aug	good	moderate	19 in.	16 in.	minor
★★	North 4 in.	*Sedum acre* 'Aureum'	yellow	⅜ in. wide	mid Jun-late Jul	fair	none	1½ in.	7 in.	none
★★	North 6 in.	*Sedum acre* 'Aureum'	yellow	⅜ in. wide	mid Jun-late Jul	excellent	none	2¼ in.	7 in.	none
★★★	North 8 in.	*Sedum acre* 'Oktoberfest'	white	⅜ in. wide	mid Jun-late Jul	excellent	none	2 in.	7 in.	none
★★	North 8 in.	*Sedum album*	white	¼ in. wide	late Jun-late Jul	poor	none	2 in.	7 in.	none
★★	North 8 in.	*Sedum album* 'Chloroticum'	white	¼ in. wide	late Jun-late Jul	fair	none	2 in.	7 in.	none
★★	North 4 in.	*Sedum album* 'Coral Carpet'	white	¼ in. wide	late Jun-late Jul	fair	none	2 in.	6 in.	none
★★	North 6 in.	*Sedum album* 'Coral Carpet'	white	¼ in. wide	late Jun-late Jul	fair	none	2 in.	8 in.	none
★★★★	North 6 in.	*Sedum hybridum* 'Immergrünchen'	yellow	⅝ in. wide	Jun	good	none	5 in.	spreading	none
★★★★	North 6 in.	*Sedum kamtschaticum* ssp. *ellacombeanum*	yellow	½ in. wide	mid Jun-late Jul	good	none	9 in.	spreading	none
★★★★	North 6 in.	*Sedum kamtschaticum* var. *floriferum* 'Weihenstephaner Gold'	yellow	⅝ in. wide	Jun	good	none	4 in.	spreading	none
★★★★	North 4 in.	*Sedum kamtschaticum* 'Variegatum'	yellow	¾ in.	early Jun-early Jul	excellent	none	5 in.	spreading	none
★★	North 4 in.	*Sedum pachyclados*	n/a	n/a	did not flower	n/a	n/a	2 in.	12 in.	none
★★	North 6 in.	*Sedum pachyclados*	creamy white	½ in. wide	mid May-early Jun	poor	none	2 in.	10 in.	none
★★	North 8 in.	*Sedum pachyclados*	creamy white	½ in. wide	mid May-early Jun	poor	none	4 in.	16 in.	none
★★★★	North 4 in.	*Sedum rupestre* 'Angelina'	yellow	¾ in.	late Jun-late Jul	fair	none	4 in.	12 in.	none
★★★	North 4 in.	*Sedum rupestre* 'Blue Spruce'	golden-yellow	1 in.	mid Jun-early Aug	good	none	5 in.	10 in.	none
★★★	North 6 in.	*Sedum rupestre* 'Blue Spruce'	golden-yellow	1 in.	mid Jun-early Aug	good	none	3 in.	10 in.	none
★★★	North 4 in.	*Sedum sexangulare*	yellow	⅜ in.	late Jun-late Jul	excellent	none	4 in.	spreading	none
★★★★	North 4 in.	*Sedum spurium* 'John Creech'	pink	¾ in.	mid Jun-late Jul	good	none	3 in.	18 in.	none
★★★★	North 4 in.	*Sedum spurium* var. *album* 'Leningrad White'	white	¾ in.	late Jun-early Aug	good	none	3 in.	7 in.	none
★★★★	North 6 in.	*Sedum spurium* var. *album* 'Leningrad White'	white	¾ in.	late Jun-early Aug	good	none	4 in.	10 in.	none
★★★★	North 8 in.	*Sedum spurium* var. *album* 'Leningrad White'	white	¾ in.	late Jun-early Aug	good	none	4 in.	spreading	none
★★★	North 4 in.	*Sedum ternatum* 'Larenim Park'	white	½ in. wide	late May-Aug	poor	none	5 in.	30 in.	none
★★★	North 4 in.	*Sempervivum* 'Blue Boy'	pink, white	⅝ in. wide	mid Jul-early Aug	good	none	8 in.	4 in.	minor

★★★	North 4 in.	*Sempervivum* 'Le Clair's Form'	white	1¼ in. wide	mid Jun-mid Jul	fair	none	6-8 in.	4-5 in.	none
★★	North 6 in.	*Sempervivum* 'Le Clair's Form'	white	1 in. wide	late Jul-mid Aug	poor	none	2-5 in.	2-5 in.	none
★★★★	North 6 in.	*Sesleria caerulea*	green	n/a	mid May-Aug	fair	low	24 in.	12 in.	minor
★★	South 4 in.	*Sisyrinchium albidum*	white	¾ in. wide	late Apr-early Jun	excellent	none	7 in.	8 in.	moderate
★★	South 6 in.	*Sisyrinchium albidum*	white	¾ in. wide	late Apr-early Jun	excellent	none	7 in.	6 in.	moderate
★★★★	South 8 in.	*Solidago rigida*	yellow	6 in. wide	mid Aug-mid Oct	good	none	58 in.	22 in.	minor
★★★★	North 8 in.	*Solidago* 'Wichita Mountains'	yellow	6 in. long	mid Sep-mid Nov	excellent	none	33 in.	18 in.	minor
★★★★★	North 6 in.	*Sporobolus heterolepis*	green, purple	n/a	Aug-Sep	fair	none	48 in.	42 in.	minor
★★★★★	North 8 in.	*Sporobolus heterolepis*	green, purple	n/a	Aug-Sep	excellent	none	39 in.	35 in.	minor
★★★★	South 4 in.	*Sporobolus heterolepis*	green, purple	n/a	Aug-Sep	excellent	none	37 in.	26 in.	moderate
★★★★	South 6 in.	*Sporobolus heterolepis*	green, purple	n/a	Aug-Sep	good	none	40 in.	26 in.	minor
★★★★	South 8 in.	*Sporobolus heterolepis*	green, purple	n/a	Aug-Sep	good	none	39 in.	36 in.	minor
★★★★★	North 4 in.	*Sporobolus heterolepis* 'Tara'	green, purple	n/a	Aug-Sep	excellent	none	36 in.	44 in.	minor
★★★★★	North 8 in.	*Sporobolus heterolepis* 'Tara'	green, purple	n/a	Aug-Sep	excellent	none	27 in.	30 in.	minor
★★	North 8 in.	*Stachys byzantina* 'Big Ears'	n/a	n/a	did not flower	n/a	none	6 in.	14 in.	minor
★★	North 4 in.	*Stachys byzantina* 'Silver Carpet'	n/a	n/a	did not flower	n/a	none	6 in.	12 in.	minor
★★★	South 6 in.	*Symphyotrichum ericoides*	white	¼ in. wide	early Aug-early Oct	excellent	none	33 in.	17 in.	moderate
★★★	South 8 in.	*Symphyotrichum ericoides*	white	¼ in. wide	early Aug-early Oct	excellent	none	28 in.	14 in.	moderate
★★★★	North 4 in.	*Symphyotrichum ericoides* 'Snow Flurry'	white	⅜ in. wide	mid Sep-early Nov	good	none	3 in.	11 in.	minor
★★★★	North 6 in.	*Symphyotrichum ericoides* 'Snow Flurry'	white	⅜ in. wide	mid Sep-early Nov	good	none	1 in.	12 in.	minor
★★	North 8 in.	*Symphyotrichum ericoides* 'Snow Flurry'	white	½ in. wide	mid Sep-early Nov	poor	none	3 in.	16-25 in.	minor
★★★	South 8 in.	*Symphyotrichum laeve*	light purple	1 in. wide	mid Sep-mid Nov	excellent	none	52 in.	22 in.	moderate
★★	South 6 in.	*Symphyotrichum novae-angliae*	light purple	1½ in. wide	mid Sep-mid Nov	good	none	24 in.	20 in.	moderate
★★	South 8 in.	*Symphyotrichum novae-angliae*	light purple	1½ in. wide	mid Sep-mid Nov	fair	none	28 in.	20 in.	moderate
★★	South 8 in.	*Symphyotrichum oblongifolium*	light purple	1 in. wide	Sep-Oct	fair	none	21 in.	8 in.	minor
★★	North 4 in.	*Symphyotrichum oolentangiense*	lavender-blue	1 in. wide	mid Sep-late Oct	fair	none	12 in.	7 in.	moderate
★★★	South 4 in.	*Symphyotrichum oolentangiense*	lavender-blue	1 in. wide	early Sep-mid Oct	good	moderate	9 in.	3 in.	minor
★★	South 8 in.	*Symphyotrichum oolentangiense*	lavender-blue	1 in. wide	early Sep-early Nov	fair	moderate	17 in.	7 in.	moderate
★★★	North 8 in.	*Symphyotrichum sericeum*	light purple	1¼ in. wide	mid Sep-late Oct	fair	moderate	25 in.	12 in.	moderate
★★★	South 4 in.	*Talinum calycinum*	magenta	¾ in. wide	late Jun-mid Sep	good	heavy	14 in.	4 in.	none
★★★★	South 8 in.	*Tetraneuris herbacea*	yellow	1¼ in. wide	early May-early Jul	good	none	12 in.	8 in.	none
★★★	North 4 in.	*Thymus praecox* 'Coccineus'	purple	¼ in. wide	early Jun-early Aug	good	none	2 in.	24 in.	none
★★★	North 4 in.	*Thymus pseudolanuginosus*	light purple	½ in. wide	Jun	fair	none	2 in.	24 in.	minor
★★★	South 6 in.	*Tradescantia ohiensis*	lavender-blue	1½ in. wide	early Jun-late Jul	fair	low	8 in.	8 in.	minor
★★★	South 8 in.	*Tradescantia ohiensis*	lavender-blue	1½ in. wide	early Jun-early Jul	fair	low	10 in.	10 in.	minor
★★★★	South 6 in.	*Tradescantia tharpii*	rosy purple	1¾ in. wide	mid May-early Jun	excellent	none	4 in.	12 in.	minor
★★	South 4 in.	*Verbena stricta*	light purple	8 in. long	mid Jul-mid Sep	good	none	25 in.	3 in.	moderate
★★	North 6 in.	*Veronica prostrata* 'Aztec Gold'	n/a	n/a	did not flower	n/a	none	7 in.	8 in.	moderate
★★★★	South 4 in.	*Viola sagittata*	purple	¾ in. wide	late Apr-early Jun	good	moderate	6 in.	7 in.	moderate
★★★★	South 6 in.	*Viola sagittata*	purple	1 in. wide	late Apr-early Jun	good	moderate	6 in.	10 in.	moderate
★★★★	South 8 in.	*Viola sagittata*	purple	1 in. wide	late Apr-early Jun	excellent	moderate	8 in.	9 in.	moderate
★★★	North 6 in.	*Zizia aptera*	yellow	2 in. wide	late May-late Jun	good	low	20 in.	13 in.	moderate

Ratings: ★★★★★ excellent, ★★★★ good, ★★★ fair, ★★ poor, ★ very poor

[1]Reseeding Levels: low <25%; moderate 25-60%; heavy >60%

[2]Heat/Drought Stress: minor <25%; moderate 25-60%; severe >60%

Table 2: Taxa that did not complete the five-year trial

Roof	Depth	Plant Name	Year Died	Winters Survived
North	4 in., 6 in.	*Agastache astromontana* 'Pink Pop'	2014	4
North	4 in., 6 in.	*Armeria maritima* 'Alba'	2013	3
North	6 in.	*Armeria maritima* 'Rubrifolia'	2013	3
North	6 in.	*Aster alpinus* var. *albus*	2014	4
North	8 in.	*Buddleja davidii* 'Blue Chip'	2013	3
South	8 in.	*Campanulastrum americanum*	2011	1
South	6 in.	*Echinacea purpurea*	2014	4
South	4 in., 8 in.	*Erigeron caespitosa*	2013	3
North	4 in.	*Erigeron scopulinus*	2012	2
North	4 in., 8 in.	*Eriogonum umbellatum*	2013	3
North	4 in., 6 in.	*Hylotelephium sieboldii*	2013	3
North	4 in.	*Lewisia longipetala* 'Little Plum'	2014	4
North	4 in.	*Linum flavum* 'Compactum'	2013	3
South	6 in.	*Lupinus perennis*	2011	0
North	4 in., 8 in.	*Oenothera fruticosa* 'Fireworks'	2013	3
North	6 in., 8 in.	*Origanum libanoticum*	2012	2
North	6 in., 8 in.	*Origanum vulgare* 'Aureum'	2013	3
North	8 in.	*Pachysandra procumbens*	2013	2
North	8 in.	*Penstemon ×mexicali* 'Red Rocks'	2012	2
South	4 in., 6 in., 8 in.	*Rudbeckia fulgida*	2013	3
South	8 in.	*Rudbeckia hirta*	2013	3
North	6 in.	*Salvia argentea*	2014	4
North	4 in., 6 in., 8 in.	*Sedum pachyclados*	2013	3
North	4 in.	*Sempervivum* 'Blue Boy'	2013	3
North	4 in., 6 in.	*Sempervivum* 'Le Clair's Form'	2013	3
South	4 in., 6 in.	*Sisyrinchium albidum*	2013	2
North	8 in.	*Stachys byzantina* 'Big Ears'	2013	3
North	4 in.	*Stachys byzantina* 'Silver Carpet'	2013	2
South	4 in.	*Verbena stricta*	2013	2
North	6 in.	*Veronica prostrata* 'Aztec Gold'	2011	1