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Title

Investigation of plant growth and flower performance on a semi-extensive green roof

Abstract

Understanding of plant growth and flower performance is crucial for appropriate planting design. This study was aimed to understand characteristics of growth pattern and flower performance in green roof plants and how plant species diversity effect these characteristics. A semi-extensive green roof was installed in 2005 and 54 species plant species were planted in 10 cm and 20 cm of the substrate in Rotherham, UK. Thirty-two quadrats (50 cm × 50 cm) were set up through the combinations of plant species diversity (high and low), planting density (high and low). Percentage of coverage and height of each species were recorded at every month from February to November 2006 in these 32 quadrates. Flowering time of each species was studied every two weeks from February to November 2006. Flowering time was various from plants; some showed a very long flowering time, over five months whereas some finished flowering within two weeks. The growth characteristics of individual plant species over time were categorized into six patterns of coverage and vertical growth pattern. Spread of individual plants was larger in high diversity of plants than those in low diversity of plants. Number of flowering was higher and overall flowering term was longer in the quadrats of higher plant species diversity than those of lower plant diversity. However, these tendencies were affected strongly by the combination of species used. Therefore, it is important to be aware of individual plant growth characteristics such as plant size, growth pattern and flower performance for planting design.

Highlight

・Plant phenology on a semi-extensive green roof is investigated over a year.

・Flowering time of plants was various from less than two weeks to over five months.

・Plant species were categorized into six patterns of coverage and vertical growth pattern

・Plant species diversity affect plant growth and flower performance.

Keywords

Urban landscape; Planting design; Plant species diversity; Growth pattern

1. Introduction

Green roofs receive considerable attention because they are important strategies for solving urban environment problems, such as the heat island effect (Speak et al., 2013) and excessive

water runoff (Nagase & Dunnett, 2012; Versini et al., 2015), and they create habitats that increase biodiversity (Baumann, 2006; MacIvor & Lundholm, 2011). Generally, green roofs are referred to as extensive or intensive. Extensive green roofs are characterized by shallow substrate depth, light-weight, low maintenance requirements and reduced need for irrigation and can be applied to existing buildings; however, plant selection is limited. *Sedum* spp. are the most widely used plants for extensive green roofs because they can adapt to harsh environments, including shallow substrate depth, limited water availability, wide temperature fluctuations and high exposure to wind and solar radiation (Nagase & Dunnett, 2010). In contrast, intensive green roofs are characterized by thick substrate, heavy-weight, high maintenance requirements, and they generally require irrigation systems; they accommodate various plant types, including trees and shrubs. Therefore, intensive green roofs can be designed as roof gardens and are appropriate for accessible places such as commercial buildings. However, high initial cost, high maintenance and usually regular irrigation compromise their sustainability in comparison with extensive green roofs (Van Mechelen et al. 2014). Semi-extensive green roofs, sometimes called semi-intensive green roofs, combine the best features of extensive and intensive, with the same low or no input philosophy of the extensive roof and use similarly light-weight technologies. However, their slightly deeper layers of growing medium (100–200 mm) can accommodate a greater range of plant types (Dunnett & Kingsbury, 2008; Hopkins & Goodwin, 2011), and its instalment and maintenance are less expensive than those of intensive green roofs. Semi-extensive green roofs are relatively light weight and suitable for large-span roofs and retrofitting of commercial buildings (Hopkins & Goodwin, 2011). Moreover, semi-extensive green roof plants are predominantly herbaceous perennials, have long flowering and various leaf texture and colour. They are appropriate for accessible places and/or places that are visible from a small distance

57 (Dunnett & Kingsbury, 2008).

58 Recent studies have investigated the benefits of high plant diversity on green roofs
59 (Cook-Patton & Bauerle, 2012; Van Mechelen et al., 2015). Ecological studies showed benefits
60 of high plant diversity, for example, better water capture, evapotranspiration and temperature
61 reduction (Wolf & Lundholm, 2008; Lundholm et al. 2010), drought tolerance (Nagase &
62 Dunnett, 2010), reduced water runoff and summer roof temperatures and greater biodiversity
63 (Brenneisen, 2006). From an aesthetic viewpoint, diverse planting is recommended. Lee et al.
64 (2014) studied green roof preference using photographs and showed increasing diversity was
65 associated with higher preferences overall. More complex plant combinations may comprise
66 various forms that enhance visual and structural diversity of the planting, and well-selected
67 combinations provide diversity of form and colour and offer a long cumulative flowering season
68 (Dunnett & Kingsbury, 2008). Therefore, studies on green roof plants are rapidly expanding the
69 choices of plants for extensive green roofs. For example, survivability and growth on extensive
70 green roofs have been studied under varying conditions of substrate type (Nagase & Dunnett,
71 2011; Razzaghmanesh et al., 2014), substrate depth (Boivin et al., 2001; Rowe et al., 2012) and
72 irrigation (Kanechi et al., 2014). However, plant studies tend to be focused on survivability and
73 function, with little consideration for planting design. Growth patterns and flower performance
74 through growing seasons can be crucial factors in creating compatible combinations of species
75 that together have long display seasons (Dunnett, 2004). As Snodgrass & McIntyre (2010)
76 pointed out, percentages of various species change depending on the season, temperature, rainfall
77 and various other variables. For example, some plants adapt well and spread quickly, whereas
78 others require longer and some gradually die out. Hence, knowledge of plant growth pattern and
79 flower performance could be used to inform formulations of plant combinations with continuous

flowering periods and colour combinations and leaf textures (Kircher, 1998). Previous studies of annuals (Nagase & Dunnett, 2013a; Benvenuti, 2014) and geophytes (Nagase & Dunnett 2013b) on extensive green roofs report flowering times and plant growth over 1 year and analyses of plant performance in the context of planting design. However, few studies have included herbaceous perennials in planting designs on semi-extensive green roofs.

Understanding of plant growth and flower performance is crucial for appropriate planting design, aesthetic and improved ecosystem services. In addition, it is important to consider how to combine plants in species mixtures. This study aimed to understand characteristics of growth pattern and flower performance in green roof plants and how plant species diversity affects these characteristics.

2. Methods

Experimental site

Experiments were performed on a semi-extensive green roof at Moorgate Crofts Business Centre in Rotherham, Northern England, UK from February to November 2006. The experimental site comprised 415 m^2 of accessible green roof on the fourth story of the building and was constructed on the 770 m^2 roof in the summer of 2005 (Latitude: 53.433°, Longitude: -1.356°). A floor plan is shown in Fig 1. The green roof consisted of a vapour control barrier (Hi-Ten Universal vapour barrier), 9 cm of insulation (Alumasc BGT polyurethane insulation), a waterproofing membrane (Derbigum), a root barrier (Preventol B2), a geotextile made of polypropylene with fleece backing for green roof drainage (SSM45), a drainage layer (Floradrain FD 40), a filter sheet (SF) and a substrate. The green roof was divided into a semi-extensive area (20 cm of substrate), alpine planting area and low-edge area comprising 2.5 cm of gravel mulch

over 10 cm of Zinco heather and lavender substrate (Zinco heather and lavender substrate: ≤15% of granules that were <0.063 mm in diameter, salt content ≤2.5%, total porosity 64%, pH 7.8, dry weight 940 kg/m3, saturated weight 1360 kg/m3, maximum water capacity 42%, air content at maximum water capacity 22%, water permeability ≥0.064 cm/s). The substrate analysis was carried out according to FLL guidelines. (Alumasc Exterior Building Products, 2006; FLL, 2008). In the semi-extensive area, 20 cm of the substrate was installed. In the low edge area and the alpine planting area, 2.5 cm of gravel mulch over 10cm of the substrate was installed. In these areas, underneath the substrate, 7.5 cm of crushed brick (Zincolit) was used to make up the levels. These green roofs had different substrate depths but kept the same surface height. All materials were obtained from Almasc (Northamptonshire, UK). 43 species of forbs, 5 species of grasses and 6 species of bulbs were planted in July 2005. The present 54 species are show in Table 1. Grasses are used to give winter interest, and many of the plants have seed heads. The plant species were chosen to give a very long continuity of flowering (Dunnett and Kingsbury, 2008). The plants were obtained from Chapel Cottage Plants (Cambridgeshire, UK), Van Dogeweerd (Lincolnshire, UK), Barbara Austin Perennials (Wiltshire, UK), Gedney Bulbs (Lincolnshire, UK) and Mike Handyside Wildflowers (Cheshire, UK). Planting densities were approximately 18 plants/m^2 in the semi-extensive area, 22 plants/m^2 in the alpine plant area and 18 plants/m^2 in the low edge area. The size of pot was 9 cm. A drip irrigation system was used for establishment during 2005 and then once a week in June and July 2006 because of high temperatures and low rainfall. Maximum and minimum temperatures and precipitation at Sheffield (Latitude: 53.383° ; Longitude: -1.483°) for each month in 2006 are shown in Fig.2. Weather information for Sheffield is shown because weather information for Rotherham was not available. Sheffield is located to 15 km away from Rotherham (South West) and same altitude to

Rotherham. The climate was mild; the mean maximum temperature was 25.6°C in July and the mean minimum temperature was 1.4°C in February.

Quadrat Sampling

The 32 quadrats were set up in January 2006 with dimensions of 50 cm × 50 cm. Quadrats were established in areas of visually assessed plant species diversity classes. Each quadrat contained about seven plants. High diversity areas had six different species and low species diversity had three different species. Planting density was more than 50% of total coverage in high density areas and was less than 30% in low density areas upon planting in January 2006. Initially, we determined that there were significant differences between high plant species diversity and low plant species diversity quadrats and high planting density and low planting density quadrats respectively using T-tests (α =0.05). (Minitab Release 14). Four combinations of plant species diversity and planting density included (1) low plant species diversity and low planting density, (2) low plant species diversity and high planting density, (3) high plant species diversity and low planting density and (4) high plant species diversity and high planting density. These four combinations were chosen in areas with mulch (substrate depth of 10 cm) and without mulch (substrate depth of 20 cm). There were four replications for each direction (NE, NW, SE and SW), so that 32 quadrats were placed. When the positions of the quadrats were being determined, several positions were tried and the positions that fulfilled the above criteria were chosen. Details of quadrat positions are described in Fig. 1. Weeds were removed six times in 2006 (late Feb, 19 May, 11 July, 5 August, 11 September and 12 October).

Survey of plant growth

In 32 quadrats, it was impossible to cover all 53 species but 43 plant species were found in the sampled quadrats. Percentages of coverage and vertical height (from bottom to highest leaf

149 apex) of all individual plants were recorded at the beginning of every month from February to
150 November 2006 in all quadrats. The quadrat was divided into 5 cm × 5 cm grids and percentage
151 of coverage of each species was measured by counting the number of grids.
152 With reference of Gracia-Albarad (2005), plant growth type was defined by percentage
153 of coverage, vertical height, growth pattern and best growing season from above measurement.
154 Coverage and vertical height were identified as follows: Coverage: small, <30%; medium, 30%–
155 <60%; large, ≥60 % and vertical height: low, <20 cm; medium, 20–<50 cm; high, ≥50 cm. Three
156 growth patterns were also defined as stable (little change in coverage or height over time), bell
157 curve (coverage or height increases and reaches a maximum in a certain time and then declines)
158 and plateau (coverage or height increases and then remains stable at maximum growth). Best
159 growing and flower seasons were classified as early (February–May), medium (June–August)
160 and late (September–November). Accordingly, individual plant growth was classified into six
161 categories.
162 To investigate continuity of flowering and visual qualities, photographs were obtained
163 from the same position to the direction of North West every two weeks. The position is shown in
164 Fig. 1. Flowering times of each species were recorded every 2 weeks from February to
165 November 2006. In each plant species, three representative plants were selected randomly from
166 each aspect, totalling 12 plants. They were marked and they were measured every time. The
167 flowering period was defined by the presence of flowers on one or more of the 12 plants. When
168 more than one plant of a species was flowering, the following three parameters of all 12
169 representative plants were measured and averaged. The parameters were (1) Flowering shoot
170 number (2) The relative appearance of flower, on a 1 to 5 scale: 1= Few flowers observed and
171 still they have weak visual impression; 2= About 20% of shoots have flowers, however, visual

172 impression is still weak; 3= Half of shoots have flowers and visual impression is moderate; 4=
173 About 80% shoots have flowering and visual impression is good; 5= Plants are in full bloom,
174 with high visual quality (3) Percentage of flowering plants number within 12 representative
175 plants (Number of flowering plants/12 × 100 %). Each flower colour was divided into nine, blue,
176 brown, green, orange, purple, pink, red, yellow and white.

177 To evaluate changes in overall plant cover over time, % cover of individual plants were
178 summed within a quadrat for a single sampling time. Summed cover values were compared
179 between density and diversity treatments using a repeated measures linear mixed model.
180 Residuals were normally distributed so no transformations were applied. To evaluate changes in
181 quadrat level flowering species richness over time, quadrat flowering richness values were
182 compared between initial diversity treatments using a repeated measures general linear model.
183 Transformations failed to achieve normality in the richness data due to the large number of zero
184 values. Both poisson and negative binomial models were evaluated and a negative binomial error
185 structure showed the best fit using model deviance values. These tests were carried out using R
186 version 3.3.1 (R Core Team 2016) with the lme4 package (Bates et al. 2015).

187

188 **3. Results**

189 *3.1. Flower performance*

190 Changes in the entire green roof over the study year are shown in Fig. 3. Numbers of
191 flowering species and numbers of flowering colour were recorded over a year (Fig. 4), and at
192 least three species were in flower in each month from February to November 2006. Numbers of
193 flowering species increased from April and were the highest at the end of June. Number of
194 flower colour was also highest in June. Numbers of flower species decreased thereafter, but

195 increased again in early autumn (August and September) prior to decreasing significantly after
196 September.

197 Total flowering periods of individual species and their characteristics are shown in Table
198 1 and Appendix A. Nine plant species sustained flowering performance for over 5 months, and
199 *Silene uniflora*, *Erodium ciliatum*, *Calamintha nepeta* and *Sedum kamtschaticum* var. *floriferum*
200 'Weihenstephaner Gold' had particularly high percentages of flowering plants for a long time. In
201 contrast, *Armeria maritima* 'Splendens' and *Geranium cinereum* 'Ballerina' showed low
202 percentages of flowering plants over a long time. For example, only one *Geranium cinereum*
203 'Ballerina' plant had a flower for 3 months. Moreover, some plants such as *Allium*
204 *schoenoprasum* flowered again in autumn after complete cessation of flowering in spring.
205 Overall, long flowering species had limited visual qualities at the beginning but contributed
206 gradually for a long period.

207 Except for *S. kamtschaticum* var. *floriferum* 'Weihenstephaner Gold', *Sedum* spp., bulb
208 species and grass species had short flowering periods (<1 month) and some plants such as *Allium*
209 *karataviense*, flowered for less than 2 weeks. These species also tended to produce small
210 numbers of flowers and/or start and finish flowering almost simultaneously.

211

212 *3.2. Growth characteristics of individual plant species*

213 Temporal growth characteristics of individual plant species in quadrats were analysed
214 according to coverage, vertical height and growing season duration. Classifications of individual
215 plant growth types and numbers of species in each type are presented in Table 2, and growth
216 types of individual plant species are presented in Appendix B. Change of mean coverage over
217 time in each type and change of height over time in each type are shown in Fig.5 and Fig.6

218 respectively. Type 1 and Type 2 species were characterised by the tendency for slow growth and
219 little change in coverage over time. Plants with flowers just above leaves were classified as Type
220 1 (stable height), whereas those with higher flower stems were classified as Type 2 (bell curve
221 changes in height over time). Species of these categories tended to have short heights and were
222 not very prominent in the summer; however, majority of them are evergreen and provided
223 foliage colour during the winter. Type 1 plants included low growing *Sedum* spp. such as *S. acre*
224 'Golden Queen' and those of Type 2 included *Campanula rotundifolia* and *Dianthus deltoides*.
225 Semi-evergreen species were classified as Type 3 and 4 plants; they started to grow in spring and
226 showed maximum growth in the summer and decreased coverage in autumn and winter with the
227 loss of most leaves. Species with separate flower stems such as *Erodium manescavii*, *Festuca*
228 *glauca* and *Limonium latifolium* were classified as Type 3, whereas species with flowers on top
229 of stems such as *Allium schoenoprasum*, *Origanum laevigatum* 'Herrenhausen', *Salvia* ×
230 *sylvestris* 'Herrenhausen' and *Sedum telephium* 'Matrona' were classified as Type 4. Types 5
231 and 6 grew vigorously throughout the year, with stable coverage and height after a period of
232 increase. Types 5 and 6 differed in the structure of their flower stems and included *Helicotrichon*
233 *sempervirens* and *S. uniflora* and *C. nepeta* and *Petrorhagia saxifraga*, respectively. In this
234 study, high numbers of species were classified as Types 1 and 3.

235 Smaller plants (Types 1, 2 and 3) showed their best growing seasons during early to
236 medium phases, whereas larger plants (Types 4, 5 and 6) grew best during the medium to late
237 phase. The largest number of species grew best in the middle season, followed by the late season
238 and then the early season. Therefore, species of early (*Primula veris* and *Muscari armeniacum*)
239 and late (*C. nepeta*, *E. ciliatum*, *Nepeta* × *faassenii* and *S. telephium* 'Matrona') growing seasons
240 are particularly valuable.

241

242 *3.3. Effects of plant species diversity*

243 Overall, flower performance was better in high-diversity quadrats than low-diversity quadrats.
244 Numbers of flowering plant species per quadrat differed between diversity treatments and with
245 time, with high initial diversity treatments having higher flowering species richness, but there
246 was no significant time × diversity interaction. Moreover, statistical analysis showed that
247 overall flowering months per quadrat were significantly longer in high diversity quadrats
248 (average 5.13 months) than in low diversity quadrats (average 3.56 months). The best model for
249 summed coverage included the three-way interaction between time, diversity and density. The
250 low density treatment with high initial diversity had higher coverage throughout and a less
251 pronounced decline toward the end of the growing season, compared with the low diversity low
252 density treatment. High density treatments had higher coverage throughout the growth period
253 especially from May onward (Fig. 7).

254

255 **4. Discussion**

256 *4.1. Flower performance*

257 On an accessible and visible green roof, a long bloom season with multiple flower colours
258 showed favourable qualities in a public opinion survey (Rutledge & Holloway, 1994). Moreover,
259 flower colours, flowering times and pollinator rewards help to attract pollinators and provide
260 habitat for local flora and fauna, thus supporting the ensuing ecosystem services (Van Mechelen
261 et al. 2015). Some species produced large numbers of flowers and flowered one after the other
262 and hence contributed greatly to the aesthetics of green roofs. Although flowering in winter time
263 may not contribute a useful nectar source for pollinators, it can provide some colour on green

roofs. Six species flowered in spring and again in autumn and showed long flowering periods. Similarly, some species (*Achillea* spp.) reportedly provide repeated flowering periods after being mown soon after midsummer (Kingsbury, 1996).

In the present study, species of bulbs,grasses and most *Sedum* spp. showed short flowering periods, and numbers of flowering shoots on bulb plants were limited. However, these species play important roles in the performance of green roofs because they flower at times when few other species are flowering. Grass species provide foliage colour throughout the year and *Sedum* spp. are drought tolerant and provide beautiful foliage colours in the winter. Hence, considering seasonal interests such as foliage and seed heads is necessary in addition to flowering performance.

As shown previously (Dunnett and Kingsbury, 2008; Dunnett, 2004), numbers of flowering plants per quadrat were higher and overall flowering times were longer in high-diversity quadrats than in lower-diversity quadrats. Thus, plant communities with higher plant species diversity are more likely to have longer flowering times. However, flowering times of individual plant species also contributed to these long flowering times. Hence, knowledge of flowering seasons of individual plant species is important to extend overall flowering seasons of green roofs.

4.2. Growth characteristics of individual plant species

In this study, six patterns of plant type were identified. In many cases, extensive green roofs require a shallow substrate (<10 cm) and low maintenance and are less expensive; only Type 1 and 2 plants scan be used on these. Many drought tolerant plant species form a low carpet, it would be effective to include taller perennials among them (Hausen & Stahl,

1993).With careful selection of species it is possible to achieve seasonal changes and extend the overall flowering time; the combinations of low growing to complete ground cover species (equivalent to Type 1 and 2 species), medium-height clump-forming species to form the main flowering interest of the plantation (equivalent with Type 3 and 4) and taller emergent species to provide structural and visual diversity (equivalent with Type 5 and 6) (Dunnett, 2004). To this end, awareness of plant characteristics such as growth types and seasonal interest is important to extend seasonal display.

Knowledge of growth sizes and types is useful for laying out plants on green roofs and enabling section of planting densities. Spacing between groups of herbaceous species is critical because of varying growth rates and habits. Moreover, manageable stability of boundaries between species requires consideration of canopy height, predilection to flop or make rapid lateral growth, timing of growth commencement in spring and shade-tolerance of smaller species (Hitchmough, 1994). Nevertheless, plant interactions can be positive (mutual or commensal) or negative (competitive), and these often reflect amelioration of growth- and survival-constraining environmental factors by the physical presence of another plant (Brooker & Callaghan, 1998).

4.3. Effects of plant species diversity

In the present study, the spread of individual plants increased in high-diversity quadrats (in the low density quadrats). Previous ecological studies show that diverse plant communities are more productive than monocultures because diverse communities comprise species with complementary resource use, leading to more complete and efficient use of resources, with increased nutrient uptake and more efficient water usage (Cook-Patton & Bauerle 2012). Previous studies of plant species diversity on green roofs showed no significant effects of mixed

planting on plant growth. However, incorporation of functional diversity, particularly varied growth forms, increases the diversity and potentially improves long-term resilience and performance of green roof systems (Nagase & Dunnett, 2010; Nagase & Dunnett, 2012; Heim & Lundholm, 2014). The present data indicate that combinations of species with greater functional diversity and complexity were more effective at improving cover than plants of the same taxonomic group that compete for resources, at least in the low density quadrats. However, this study was performed for 1 year during the establishment stage, necessitating longer-term studies of the effects of plant species diversity on plant growth.

5. Conclusion

In the present study, growth characteristics and flower performance of commonly used species for green roofs were identified. Moreover, the present quadrat comparisons indicated that plant species diversity affects overall flowering times and plant growth. However, although these tendencies reflected plant species diversity and planting density they varied greatly depending on the combination of species. Specifically, growth characteristics such as plant size (coverage and vertical height), growth types and flowering times are important for selecting plant species and planting designs and maintaining extensive green roof instalments. In future studies, more accurate analyses of plant growth will be facilitated by continuous measurements of substrate moisture, temperature and wind directions in different places on the roof. Moreover, long-term studies of plant performance, including growth and flower performance, are required under the present green roof conditions.

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6. References

Baumann, N., 2006. Ground-Nesting Birds on Green Roofs in Switzerland: Preliminary Observations. *Urban Habitats*, 4(1), pp.37–50. Available at: http://urbanhabitats.org/v04n01/birds_full.html.

Benvenuti, S., 2014. Wildflower green roofs for urban landscaping, ecological sustainability and biodiversity. *Landscape and Urban Planning*, 124, pp.151–161. Available at: http://dx.doi.org/10.1016/j.landurbplan.2014.01.004.

Brenneisen, S., 2006. Space for urban wildlife: Designing green roofs as habitats in Switzerland. *Urban Habitats*, 4(1), pp.27–36. Available at: http://www.urbanhabitats.org/v04n01/wildlife_full.html.

Brooker, R. W., & Callaghan, T. V., 1998. The balance between positive and negative plant interactions and its relationship to environmental gradient: a model. *Oikos*, *81,* 196–207.

Boivin, M., Lamy, M., Gosselin, A., & Dansereau, B. (2001). Effect of artificial substrate depth on freezing injury of six herbaceous erennials grown in a green roof system. *HortTechnology*, *11,* 409–412.

Cook-Patton, S.C. & Bauerle, T.L., 2012. Potential benefits of plant diversity on vegetated roofs: A literature review. *Journal of Environmental Management*, 106, pp.85–92. Available at: http://dx.doi.org/10.1016/j.jenvman.2012.04.003.

Dunnett, N., 2004. The dynamic nature of plant communities-pattern and process in designed plant communities. In N. Dunnett & J. Hitchmough (Eds.) *The Dynamic Landscape*, London: Spon Press.

Dunnett, N., & Kingsbury, N., 2008. *Planting green roofs and living walls*. Portland Oregon: Timber Press.

Gracia-Albarado, J.C. (2005) Natural patterns in time and space: inspiration for ecological planting design, University of Sheffield, Department of Landscape, PhD dissertation.

Hausen, R., & Stahl, F., 1993. *Perennials and their garden habitats*. London: Cambridge University Press.

Heim, A. & Lundholm, J., 2014. Species interactions in green roof vegetation suggest complementary planting mixtures. *Landscape and Urban Planning*, 130(1), pp.125–133. Available at: http://dx.doi.org/10.1016/j.landurbplan.2014.07.007.

Hitchmough, J., 1994. Natural neighbours. *Landscape Design* 1994, 16–22.

Hopkins, G., & Goodwin, C., 2011. *Living architecture green roofs and walls*. Collingwood: CSIRO publishing

Kanechi, M. et al., 2014. Performance of herbaceous Evolvulus pilosus on urban green roof in relation to substrate and irrigation. *Urban Forestry and Urban Greening*, 13(1), pp.184–191. Available at: http://dx.doi.org/10.1016/j.ufug.2013.08.003.

Kingsbury, N., 1996. *The New Perennial Garden*. London: Frances Lincoln

Kircher, W., 1998. Chance as planning strategy, mixed perennial plots- a performance test, Paper presented at the European Conference of landscape architecture schools, Vienna.

Lee, K.E. et al., 2014. Living roof preference is influenced by plant characteristics and diversity. *Landscape and Urban Planning*, 122, pp.152–159. Available at: http://dx.doi.org/10.1016/j.landurbplan.2013.09.011.

Lundholm, J. et al., 2010. Plant species and functional group combinations affect green roof ecosystem functions. *PLoS ONE*, 5(3).

MacIvor, J.S. & Lundholm, J., 2011. Insect species composition and diversity on intensive green roofs and adjacent level-ground habitats. *Urban Ecosystems*, 14, pp.225–241.

Met office, 2016. Historic station data in Sheffield UK, Available at

http://www.metoffice.gov.uk/pub/data/weather/uk/climate/stationdata/sheffielddata.txt

Van Mechelen, C. et al., 2015. Functional diversity as a framework for novel ecosystem design: The example of extensive green roofs. *Landscape and Urban Planning*, 136, pp.165–173. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0169204614003065.

Van Mechelen, C. et al., 2014. Plant trait analysis delivers an extensive list of potential green roof species for Mediterranean France. *Ecological Engineering*, 67, pp.48–59. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0925857414001037.

Nagase, A. & Dunnett, N., 2010. Drought tolerance in different vegetation types for extensive green roofs: Effects of watering and diversity. *Landscape and Urban Planning*, 97(4), pp.318–327. Available at: http://dx.doi.org/10.1016/j.landurbplan.2010.07.005.

Nagase, A. & Dunnett, N., 2011. The relationship between percentage of organic matter in substrate and plant growth in extensive green roofs. *Landscape and Urban Planning*, 103(2), pp.230–236. Available at: http://dx.doi.org/10.1016/j.landurbplan.2011.07.012.

Nagase, A. & Dunnett, N., 2012 Amount of water runoff from different vegetation types on extensive green roofs: Effects of plant species, diversity and plant structure. *Landscape and Urban Planning*, 104(3-4), pp.356–363. Available at: http://dx.doi.org/10.1016/j.landurbplan.2011.11.001

Nagase, A. & Dunnett, N., 2013a. Establishment of an annual meadow on extensive green roofs in the UK. *Landscape and Urban Planning*, 112, pp.50–62. Available at: http://dx.doi.org/10.1016/j.landurbplan.2012.12.007.

Nagase, A. & Dunnett, N., 2013b. Performance of geophytes on extensive green roofs in the

United Kingdom. *Urban Forestry and Urban Greening*, 12(4), pp.509–521. Available at: http://dx.doi.org/10.1016/j.ufug.2013.06.005.

Nagase, A., Dunnett, N. and Choi, M., 2013. Investigation of weed phenology in an establishing semi-extensive green roof. Ecological Engineering 58, pp.156-164. Available at: http://dx.doi.org/10.1016/j.ecoleng.2013.06.007

Razzaghmanesh, M., Beecham, S. & Kazemi, F., 2014. The growth and survival of plants in urban green roofs in a dry climate. *Science of the Total Environment*, 476-477, pp.288–297. Available at: http://dx.doi.org/10.1016/j.scitotenv.2014.01.014.

Rowe, D.B., Getter, K.L. & Durhman, A.K., 2012. Effect of green roof media depth on Crassulacean plant succession over seven years. *Landscape and Urban Planning*, 104(3-4), pp.310–319. Available at: http://dx.doi.org/10.1016/j.landurbplan.2011.11.010.

Rutledge, O. C., & Holloway, P. S., 1994. Wildflower seed mixes for interior Alaska, Research progress report no. 31, February 1994, University of Alaska Fairebanks, School of Agriculture and Land Resource Management, The Agricultural and Forestry Experiment Station.

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

Speak, a. F. et al., 2013. Reduction of the urban cooling effects of an intensive green roof due to vegetation damage. *Urban Climate*, 3, pp.40–55. Available at: http://dx.doi.org/10.1016/j.uclim.2013.01.001.

Versini, P. -a. et al., 2015. Assessment of the hydrological impacts of green roof: From building scale to basin scale. *Journal of Hydrology*, 524, pp.562–575. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0022169415001912.

Wolf, D. & Lundholm, J.T., 2008. Water uptake in green roof microcosms: Effects of plant species and water availability. *Ecological Engineering*, 33, pp.179–186.

Table 1 Total flowering periods of plant species on the green roof (months)

Very-long-term flowering (5.0– 7.5 months)		colour	Long-term flowering (3.0–4.5 months)		colour	Medium-term flowering (1.5–2.5 months)		colour	Short-term flowering (0–1.0 month)		colour
Armeria maritima 'Splendens'	7.5	Pink	*Petrorhagia saxifraga,*	4.5	Pink	*Limonium latifolium*	2.5	Blue	*Armeria juniperifolia*	1.0	Pink
Geranium cinereum 'Ballerina',	7.5	Pink	*Galium verum*	4.0	White	*Melica ciliata*	2.5	Brown	*Festuca amethystina*	1.0	Brown
Silene uniflora	6.5	White	Gypsophila repens 'Dorothy Teacher',	4.0	Pink	*Sedum telephium* 'Matrona'	2.5	Pink	*Festuca glauca*	1.0	Brown
Erodium ciliatum	6.5	Pink	*Nepeta × faassenii,*	4.0	Blue	*Kniphofia* 'Border Ballet'	2	Orange	*Helictotrichon sempervirens*	1.0	Brown
Allium schoenoprasum	6.0	Pink	*Primula veris,*	4.0	Yellow	*Sedum hispanicum* 'Silver Cover'	2	White	*Muscari armeniacum*	1.0	Blue
Campanula rotundifolia	6.0	Blue	Salvia × sylvestris 'Blauhügel'	4.0	Purple	*Sedum sexangulare*	2	Yellow	*Pulsatilla vulgaris*	1.0	Purple
Erodium manescavii	6.0	Pink	*Aster amellus*	3.5	Blue	*Centaurea scabiosa*	1.5	Purple	*Sedum acre* 'Golden Queen'	1.0	Yellow
Calamintha nepeta	5.0	Pink	*Geranium. endressii* 'Wargrave Pink'	3.5	Pink	*Dianthus deltoides*	1.5	Pink	*Sedum spurium* 'Green Mantle'	1.0	Yellow
Sedum kamtschaticum var. *floriferum* 'Weihenstephaner Gold'	5.0	Yellow	*Origanum laevigatum* 'Herrenhausen'	3.0	Pink	*Euphorbia cyparissias* 'Fens Ruby'	1.5	Yellow	*Stipa tenuissima*	1.0	Brown
						Geranium lucidum	1.5	Pink	*Tulipa tarda*	1.0	Yellow
						Helianthemum nummularium 'Wisley Primrose'	1.5	Yellow	*Verbascum phoeniceum*	1.0	Blue
						Lavandula angustifolia 'Hidcote'	1.5	Purple	*Allium karataviense*	0.5	Pink
						Leucanthemum ×superbum	1.5	White	*Allium caeruleum*	0.5	Blue
						Sedum album 'Coral Carpet'	1.5	White	*Crocus tommasinianus* 'Whitewell Purple'	0.5	Purple
						Sedum 'Herbstfreude'	1.5	Pink	*Phlox douglasii*	0.5	Pink
						Sisyrinchium striatum	1.5	Yellow	*Sedum reflexum*	0.5	Yellow
						Stachys byzantina 'Silver Carpet'	1.5	Purple	*Sempervivum arachnoideum*	0.5	Pink
									Tulipa praestans 'Fusilier'	0.5	Red
									Sedum spathulifolium var. *purpureum*	0	Yellow

Table 2 Classification of plant growth types and numbers of species

	Coverage		Vertical		Best growing Season	Number of species
	Size	Pattern	Size	Pattern		
Type 1	Small	Stable	Low	Stable	Early–Medium	14
Type 2	Small	Stable	Low–Medium	Bell curve	Early–Medium	6
Type 3	Small–Large	Bell curve	Low–Tall	Bell curve	Early–Medium	11
Type 4	Medium	Bell curve	Medium–Tall	Plateau	Medium–Late	4
Type 5	Medium–Large	Plateau	Low–Tall	Bell curve	Medium–Late	5
Type 6	Medium–Large	Plateau	Medium–Tall	Plateau	Medium–Late	3

Coverage size: Small, <30%; Medium, 30% –<60%; Large, ≥60%
Vertical size: Low, <20 cm; Medium, 20–<50 cm; High, ≥50 cm
Coverage and vertical pattern: Stable, little change in coverage or height over time; Bell curve, coverage or height increases and reaches a maximum in a certain time and then declines; Plateau, plant coverage or height increases and remains stable after reaching maximum growth.
Best growing season: Early, February–May; Medium, June–August; Late, September–November.

Appendix A Flowering periods and flower performance of plant species

		February		March		April		May		June		July		August		September		October		November	
Allium caeruleum	FP									100											
	SN									2.2											
	VA									3.0											
Allium karataviense	FP								100.0												
	SN								1.0												
	VA								2.8												
Allium schoenoprasum	FP				8.3	8.3	8.3	8.3	83.3	100.0						58.3	66.7	50	75	8.3	8.3
	SN				0.1	0.2	0.1	0.1	3.9	48						1.4	1.3	0.9	1.0	0.1	0.1
	VA				0.1	0.1	0.1	0.1	2.5	4.1						0.8	0.8	0.6	0.8	0.1	0.1
Armeria juniperifolia	FP						91.7	100													
	SN						4.4	15.4													
	VA						1.2	3.3													
Armeria maritima 'Splendens'	FP		8.3	8.3					91.7	100.0	58.3	50.0	33.3	41.7	25.0	16.7	8.3	25.0	25.0	25.0	25.0
	SN		0.1	0.1					6.4	12.3	1.6	1.1	0.7	0.5	0.3	0.2	0.1	0.3	0.6	0.6	0.5
	VA		0.1	0.1					2.9	3.2	0.8	0.7	0.3	0.4	0.3	0.2	0.1	0.3	0.3	0.5	0.3
Aster amellus	FP												58.3	83.3	100.0	100.0	100.0	91.7	25.0		
	SN												2.4	2.8	4.8	6.3	7.7	3.0	1.1		
	VA												1.2	2.1	2.4	3.6	3.9	1.4	0.3		
Calamintha nepeta	FP											100.0	100.0	100.0	100.0	75.0	41.7	33.3	33.3	16.7	25.0
	SN											34.5	39.2	33.8	30.3	8.5	2.8	3.8	4.1	0.5	0.4
	VA											2.6	3.1	2.8	2.3	1	0.4	0.7	0.8	0.2	0.2
Campanula rotundifolia	FP	8.3	8.3							66.7	100.0	100.0	50.0	41.7	41.7	58.3	25.0	16.7	16.7		
	SN	0.3	0.3							3.0	7.4	4.6	0.8	0.8	0.9	1.0	0.3	0.2	0.2		
	VA	0.2	0.2							1.2	2.9	2.3	0.7	0.6	0.8	0.7	0.3	0.2	0.2		
Centaurea scabiosa	FP										91.7	75.0	16.7								
	SN										7.8	7.4	0.2								
	VA										2.8	2.9	0.2								
C. tommasinianus 'Whitewell Purple'	FP					100															
	SN					1.2															
	VA					1.7															
Dianthus deltoides	FP									100.0	100.0	66.7									
	SN									29.3	28.7	3.7									

	VA									3.4	3.3	0.9									
Erodium ciliatum	FP								91.7	100.0	100.0	91.7	100.0	100.0	100.0	100.0	100.0	91.7	83.3	16.7	16.7
	SN								8.5	22	30.7	23.2	25.8	18.3	17	18.3	15.5	10.7	2.7	1.3	0.7
	VA								2.0	3.5	3.3	3.1	3.3	3.1	3.0	3.3	2.4	2.1	1.3	0.3	0.3
Erodium manescavii	FP						8.3	8.3	100.0	100.0	75.0	41.7	33.3	83.3	91.7	91.7	41.7	16.7			
	SN						0.1	0.1	8.4	5.5	1.8	0.9	0.5	2.8	3.4	2.2	0.8	0.2			
	VA						0.2	0.1	2	2.4	1.1	0.5	0.3	2.2	2.3	1.9	0.8	0.2			
Euphorbia. cyparissias 'Fens Ruby'	FP							100	100	100											
	SN							28.7	46.7	37.8											
	VA							2.6	3.1	4.5											
Festuca amethystina	FP								100	100											
	SN								138.3	135.9											
	VA								2.9	3.5											
Festuca glauca	FP								100	100											
	SN								173.7	166.3											
	VA								3.3	3.8											
Galium verum	FP										100.0	83.3	75.0			66.7	58.3	25.0	8.3	8.3	
	SN										73.8	54.4	1.7			3.4	4.8	1	0.5	0.1	
	VA										3.8	2.3	0.7			3.8	0.8	0.3	0.1	0.1	
Geranium cinereum 'Ballerina'	FP	8.3	8.3	8.3	8.3	8.3				100.0	33.3	75.0	75.0	50.0	83.3	83.3	25.0			8.3	8.3
	SN	0.2	0.2	0.3	0.2	0.2				14.8	1.5	2.6	2.2	0.9	2.8	1.8	0.5			0.2	0.1
	VA	0.1	0.1	0.1	0.1	0.1				3.6	0.7	1.2	1.1	0.8	2	1.3	0.4			0.1	0.1
Geranium. lucidum	FP								100.0	100.0	66.7										
	SN								35.9	14.9	2.7										
	VA								3.3	2.3	1.2										
Geranium endressii 'Wargrave Pink'	FP									100.0	100.0	83.3	8.3		33.3	16.7	8.3				
	SN									8.8	6.2	2.1	0.1		0.6	0.2	0.1				
	VA									2.5	2.7	1.2	0.1		0.3	0.2	0.1				
Gypsophila repens 'Dorothy Teacher'	FP									100.0	41.7		75.0	75.0	83.3	75.0	75.0	8.3			
	SN									21.8	1.6		1.8	2.3	7.5	8.6	6.1	0.1			
	VA									3	0.6		0.8	0.8	2.3	1.4	1.3	0.1			
Helianthemum nummularium 'Wisely primrose'	FP									100.0	50.0	25.0									
	SN									4.8	2.0	0.7									
	VA									1.9	1.3	0.4									
Helictotrichon	FP									100	100										

sempervirens	SN									32.1	32.4										
	VA									3.0	2.3										
Kniphofia Border Ballet'	FP									58.3	91.7	91.7	16.7								
	SN									0.8	1.4	1.7	0.2								
	VA									2.2	2.3	1.9	0.4								
Lavandula angustifolia 'Hidcote'	FP										100.0	100.0	25.0								
	SN										6.0	11.5	0.3								
	VA										3.0	2.8	0.3								
Leucanthemum × *superbum*	FP										100.0	100.0	58.3								
	SN										13.6	19.2	1.8								
	VA										3.3	3.9	0.6								
Limonium latifolium	FP										41.7	75.0	91.7	100.0	75.0						
	SN										2.3	3.4	3.7	3.1	1.5						
	VA										1.4	2.8	3.7	2.8	1.3						
Melica ciliata	FP									100	100						100	100	100		
	SN									58	57.3						1	0.8	0.6		
	VA									2.9	3.3						0.5	0.3	0.3		
Muscari armeniacum	FP						100	100													
	SN						1.3	1.4													
	VA						2.8	3.2													
Nepeta × *faassenii*	FP						75.0	100.0	100.0	100.0						58.3	58.3	33.3	33.3		
	SN						7.4	28.9	39.5	9.6						1.9	3.4	2.8	0.8		
	VA						1.2	3.1	3.6	1.3						0.8	0.8	0.5	0.4		
Origanum laevigatum 'Herrenhausen'	FP											100.0	100.0	100.0	100.0	100.0	33.3				
	SN											16.3	26.2	18.8	16.2	10.2	1.0				
	VA											2.7	4.5	2.9	1.9	1.5	0.3				
Petrorhagia saxifraga	FP										100.0	100.0	100.0	100.0	100.0	100.0	100.0	75.0	83.3		
	SN										205.2	228.5	45	120.8	223.7	162.1	32.3	10.8	6.5		
	VA										4.1	3.3	1.5	2.3	3.3	3.3	1.3	0.8	1.0		
Phlox douglasii	FP								91.7												
	SN								27.2												
	VA								2.1												
Primula veris	FP	33.3	33.3	75.0	75.0	100.0	100.0	100.0	58.3												
	SN	0.3	0.4	0.8	1.3	1.7	12.1	16.8	2.6												
	VA	0.3	0.3	0.8	1	1.5	4.3	4.9	0.6												

Pulsatilla vulgaris	FP						58.3	100.0													
	SN						1.1	1.9													
	VA						1.8	2.7													
Salvia ×sylvestris	FP									100.0	100.0	100.0	50.0	41.7	58.3	50.0	33.3				
`Blauhügel'	SN									13.2	13.4	10.3	2.1	1.3	2.2	1.2	0.5				
	VA									3.7	3.3	1.3	0.5	0.4	0.6	0.5	0.3				
Sedum acre	FP										100	25									
'Golden Queen'	SN										59.3	0.4									
	VA										26	0.3									
Sedum album	FP									50.0	100.0	8.3									
'Coral Carpet'	SN									18.7	38.6	0.4									
	VA									1.4	3.5	0.1									
Sedum kamtschaticum	FP								100.0	100.0	58.3	66.7	75.0	83.3	100.0	100.0	83.3	25.0			
var. *floriferum* '	SN								12.5	14.7	2.8	5.6	4.9	8.7	21.8	28.6	8.7	0.8			
Weihenstephaner Gold'	VA								2.4	1.4	0.7	0.9	1	1.7	2.4	2.6	1.2	0.3			
Sedum'Herbstfreude'	FP																	83.3	75	91.7	
	SN																	3.1	1.8	0.2	
	VA																	1.7	0.8	0.1	
Sedum hispanicum	FP									91.7	83.3	58.3	41.7								
'Silver carpet'	SN									117.9	31.9	1.8	2.8								
	VA									2.8	1.5	0.6	0.4								
Sedum reflexum	FP										100										
	SN										18.9										
	VA										3.1										
Sedum sexangulare	FP										100.0	100.0	91.7	41.7							
	SN										79.2	133.7	2.6	0.5							
	VA										3.7	4.1	0.9	0.4							
Sedum spurium	FP											83.3	16.7								
'Queen Mantle'	SN											8.3	0.2								
	VA											2	0.2								
Sedum telephium	FP													83.3	100.0	100.0	83.3	16.7			
'Matrona'	SN													2.3	9.8	9.5	5.2	0.2			
	VA													1.1	2.7	2.8	1.1	0.2			
Sempervivum	FP										8.3										
arachnoideum	SN										0.1										

	VA										0.1										
Silene uniflora	FP								83.3	100.0	100.0	83.3	100.0	100.0	100.0	91.7	8.3	16.7	8.3	8.3	8.3
	SN								16.8	87	15.3	10.5	18.1	22.1	17.3	13.2	1.3	1.3	1.3	1.8	0.9
	VA								2.0	3.4	1.5	1.3	2.1	1.6	1.8	1.3	0.2	0.3	0.2	0.2	0.2
Sisyrinchium striatum	FP									100	100	58.3									
	SN									20.5	22.1	3.9									
	VA									3.5	2.8	0.7									
Stachys byzantina 'Silver Carpet'	FP										100	100	58.3								
	SN										17.1	13.3	1.2								
	VA										3.4	3.2	0.6								
Stipa tenuissima	FP										100	100									
	SN										202.3	283.3									
	VA										2.9	3.3									
Tulipa tarda	FP						75.0	66.7													
	SN						0.3	0.5													
	VA						0.6	1.1													
Tulipa praestans 'Fusilier'	FP							100													
	SN							1.2													
	VA							2.8													
Verbascum phoeniceum	FP								100.0	75.0											
	SN								2.0	1.1											
	VA								2.1	1											

Highlighted colour indicates flower colour.
P=Mean percentage of flowering plants (%), S=Mean flower shoot number, A=Mean value of appearance (1= Only little number of flower is observed and still they have weak flower impression. 2= About 20% of shoots have flowering, however, impression is still weak 3= Half of shoots have flowering and visual impression is moderate 4= About 80% shoots have flowering and visual impression is good 5= Plants are in full bloom, with high visual quality)

Appendix B Growth types of plant species

Species	Coverage		Vertical		Season			Growth type
	Size	Pattern	Size	Pattern	Growing season	Flower season	Flower term	
Allium schoenoprasum	Medium	Plateau	Medium	Plateau	Medium and Late	Early to Late	Short to Long	5
Armeria juniperifolia	Small	Stable	Low	Stable	Early–Medium	Early	Short	1
Allium caeruleum	Small	Bell curve	Medium	Bell curve	Medium	Medium	Short	3
Aster amellus	Medium	Stable	Tall	Bell curve	Medium-Late	Medium	Short	2
Calamintha nepeta	Medium	Plateau	Tall	Plateau	Medium-Late	Medium-Late	Medium	6
Campanula rotundifolia	Small	Stable	Low (Medium in flower)	Bell curve	Medium	Medium-Late	Medium to Long	2
Centaurea scabiosa	Medium	Bell curve	Medium	Bell curve	Medium	Medium	Short	3
Dianthus deltoids	Small	Stable	Low	Bell curve	Medium	Medium	Short	2
Erodium ciliatum	Small	Stable	Low	Stable	Late	Medium-Late	Long	1
Erodium manescavii	Small	Bell curve	Medium	Bell curve	Medium	Medium	Medium	3
Festuca amethystine	Small	Stable	Medium (Tall in flower)	Bell curve	Medium	Medium	Short	2
Festuca glauca	Medium	Bell curve	Medium (High in flower)	Bell curve	Medium-Late	Medium	Short-Medium	3
Galium verum	Medium	Bell curve	Medium	Bell curve	Medium-Late	Medium	Short	3
Geranium cinereum 'Ballerina'	Small	Stable	Low	Bell curve	Late	Medium-Late	Long	2
Geranium endressii 'Wargrave Pink'	Medium Small(6,14)	Bell curve	Low (Medium in flower)	Bell curve	Medium-Late	Medium	Short-Medium	3
Helianthemum nummularium 'Wisley Primrose'	Small	Stable	Low	Stable	Early-Medium,	Medium	Short	1
Helictotrichon sempervirens	Medium	Plateau	Medium (High in flower)	Bell curve	Medium-Late	Medium	Short	5
Lavandula angustifolia 'Hidcote'	Small	Stable	Low	Bell curve	Medium	Medium	Short	2
Leucanthemum × *superbum*	Medium -Large	Bell curve	Medium (Tall in flower)	Plateau	Medium	Medium	Short	4

Limonium latifolium	Medium -Large	Bell curve	Medium (Tall in flower)	Bell curve	Medium	Medium	Medium	3
Melica ciliata	Medium	Plateau	Tall	Bell curve	Medium	Medium	Short	5
Muscari arachnoideum	Small	Stable	Low	Bell curve	Early-Medium	Early	Short	2
Nepeta × faassenii	Large	Plateau	Medium	Bell curve	Late	Medium-Late	Medium	5
Origanum laevigatum 'Herrenhausen'	Medium	Bell curve	Medium	Plateau	Medium-Late	Medium-Late	Medium	4
Petrorhagia saxifrage	Medium	Plateau	Medium	Plateau	Medium-Late	Medium-Late	Medium-Long	6
Phlox douglasii	Small	Stable	Low	Stable	Early	Medium	Short	1
Primula veris	Small	Stable	Low	Stable	Early	Early	Short- Medium	1
Pulsatilla vulgaris	Small	Bell curve	Low	Bell curve	Medium	-	-	3
Salvia × sylvestris 'Blauhügel'	Medium	Bell curve	Medium	Plateau	Late	Medium	Medium	4
Sedum acre 'Golden Queen'	Small	Stable	Low	Stable	Medium	Medium	Short	1
Sedum album 'Coral carpet'	Small	Stable	Low	Stable	Medium	Medium	Short	1
Sedum kamtschaticum var. *floriferum* 'Weihenstephaner Gold'	Small - Medium	Stable	Low	Stable	Medium	Early-Late	Short-Long	1
Sedum hispanicum 'Silver Carpet'	Small	Stable	Low	Stable	Medium	Medium	Short	1
Sedum reflexum	Small	Stable	Low	Stable	Medium	Medium	Short	1
Sedum sexangulare	Small	Stable	Low	Stable	Medium	Medium	Short	1
Sedum spathulifolium ' var. *purpureum*	Small	Stable	Low	Stable	Early-Medium	-	-	1
Sedum spurium 'Green Mantle'	Small	Stable	Low	Stable	Medium-Late	-	-	1
Sedum telephium 'Matrona'	Medium	Bell curve	Medium	Plateau	Medium-Late	Medium-Late	Medium	4
Sempervivum arachnoideum	Small	Stable	Low	Stable	Medium	-	-	1
Silene uniflora	Medium-Large	Plateau	Low	Bell curve	Medium-Late	Medium-Late	Long	5

Sisyrinchium striatum	Large	Bell curve	High	Bell curve	Medium	Medium	Short	3
Stipa tenuissima	Large	Plateau	High	Plateau	Medium	Medium	Short	6
Stachys byzantina 'Silver Carpet'	Medium-Large	Plateau	Low (Medium-High in flower)	Bell curve	Medium	Medium	Short-Medium	5
Verbascum phoeniceum	Small	Bell curve	Low (High in flower)	Bell curve	Medium	Medium	Short	3