Media Modifications for Native Plant Asemblages on Extensive Green Roofs

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MEDIA MODIFICATIONS FOR NATIVE PLANT ASSEMBLAGES ON GREEN ROOFS

Richard K. Sutton

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Abstract

Great Plains and Midwestern regions might profit from selecting species representing nearby mid and short grass prairies, not the tall grass prairie. Such assemblages should exhibit needed characteristics desirable on low-input extensive green roofs to withstand stresses of: drought, heat, cold, nutrient deficiencies and wind before providing expected benefits. While published research, and its recommendations are inconclusive or negative regarding efficacy of native prairie species for extensive green roofs, establishment data gathered in this study demonstrates placing native plant assemblages for extensive green roofs into modified media significantly improves their establishment and growth.

In the short-term soil doughtiness limits plant establishment on green roofs; in the long-term availability of micro-nutrients may limit plant growth and survival. This integrated study examined the use of a hydro-absorbent polymer gel (Horta-Sorb™) and native prairie soil microbes in the initiation of an extensive green roof planted with native grasses, sedges and forbs. After one growing season results showed enhanced plant vigor from hydro-absorbent polymer gel application and its interaction with mycorrhizae inoculation. Results on specific species performance will be reported elsewhere.

Introduction

One of the features defining the Great Plains is its potential evapo-transpiration (PET) gradient that increases westward and southward across the Great Plains (25). PET and rainfall influence prairie plant communities and are also two key aspects of the environmental context for green roof vegetative cover. Green roof plant establishment and survival are strongly affected by PET and precipitation though mediated by the species and growing media chosen.

Monterusso et al (2005, p. 395) make this statement about prairie plants when only testing tallgrass prairie species, “… many native plants are not suitable for extensive green roof
systems because of harsh environmental conditions and shallow substrates”(21). Getter and Rowe (2006 p.1281) suggest looking at short grass prairies and to “consider plants found further west in locations such as Colorado. These [plant] communities receive less annual rainfall and many have shallower root systems”(10). Aridity and soil depth also define differences between short-grass and tall-grass prairie. As well, increases in potential evapotranspiration, in-solation, summer temperatures, cold winter temperatures and diurnal and seasonal temperature fluctuations and short and long-term drought oscillations all influence growth and establishment of the short and mid-grass prairie communities. These characteristics also happen to closely fit the harsh growing environment of extensive green roofs even into the more humid tall grass prairie region of eastern Nebraska and Kansas, Illinois, Indiana, Iowa, southern Minnesota and northern Missouri.

Snodgrass and Snodgrass (2006, p. 65) have also raised further doubts about native prairie plants use saying, “. . . replicating a native prairie … may not be possible on a green roof, simply because it is not a native environment and can not accommodate the spectrum of taxa that make up a prairie.”. Later they state, “Many natives have evolved in deep soils of a particular structure and microbial and nutrient balance.” (27). Many native prairie plants have not. (Figure 1) While recreating a prairie may never be possible in any circumstance, it is

Figure 1. Little bluestem (Schizachryium scoparium) and aster (Aster spp.) growing on a limestone outcrop in the shortgrass prairie biome of southwestern Nebraska. The average precipitation there is about 500 mm (19 inches) per year and PET routinely exceeds precipitation. Outcrop soil depth is around 3.75 cm (1.5 in).
possible to specify a prairie-like plant assemblage as an analogue more like a natural community that fits the harsh requirements of an extensive green roof. Thousands of acres of prairie-like plantings have been successful across North America. For example, as policy, road sides in Nebraska (22) and Iowa (13) are planted to native prairie grasses and forbs. Since the 1990’s hundreds of thousands of acres have been planted to native grasses as a part of the federal government’s Conservation Reserve Program (24). These widespread, long-term uses demonstrate native grasses and forbs can be as easy to employ as creating the Sedum monoculture dominating today’s extensive green roofs.

Ecosystem designers should consider bio-diversity for the long-term success and sustainability of an individual roof project and the environment in general. On an extensive green roof, anthropogenic plant assemblages will change over time like any living system and the composition of species is part of that change (6, 17, 23). Plant assemblages should include taxonomic but also seasonal and life-form diversity where possible. Annuals as well as perennials, grasses, forbs and sedges add to the survivability and diversity of plant structure and function, though plant communities are mediated by dominant and often co-dominate plants (23). Diversity of plant structure can lead to supporting a diversity of animal life. It should be possible to think more about community when designing the media/plant portion of a green roof because the designer has nearly absolute control over what is planted, when it is planted, into what is chosen for the media and how it is managed. Selection should not only consider lower plant forms such as mosses and bryophytes but also organic components of the growing media and microbes, especially mycorrhizae. (6, 23)

Sedum overuse on extensive green roofs may become a future problem. Monocultures generally are unstable and often given to catastrophic changes (11). Planting monocultures of a single species or genus on tens of thousands of square feet of urban roof tops will inevitably lead to problems with insects and diseases. The Sedum genus and its species already are susceptible to molds, fungi and root rots and several Sedum species are susceptible to insects.

Study Goals

Establishment moisture is the first critical part of planting green roofs. For the last 20-30 years the horticulture industry has tried various potting media modifications like hydro-absorbent polymer gels to reduce plant moisture stress, especially for plants grown in restricted root environments (3, 5, 6, 9). Such gels may have been used in green roof plantings (2), however, there appears to be no published research on the efficacy of hydro-absorbent gels for supplying moisture to green roof media. Can green roof plant establishment and growth be enhanced with addition of super absorbent polymer gel?

In order for green roofs to be more sustainable, they should require no supplemental fertilization. In natural (14) and anthropogenic (16) plant communities nutrient cycling in soil is enhanced by the symbiotic interaction of plant roots and micro-organisms. For example, mycorrhizae enhance plant growth, especially where added to subsoil or sterile media (1, 18)
and have specifically improved the growth of three native forbs (32). Soil microbes form a community that interacts with the community of plants (12). Can a prairie microbial community be initiated in green roof media to aid uptake of water and cycling of nutrients and thus growth and establishment?

Methods and Materials

These two questions, plus an examination of the suitability of short and mid grass prairie plant species, underpinned experiments made on the Pioneer Park Nature Center (PPNC) green roof in Lincoln, Nebraska. The PPNC planting site was an 83.6 m² (900 ft²) extensive green roof with 9 cm (3.5 inches) of 95% rooflite™ and 5% compost by volume placed over a Hydrotech Gardenroof™ system. Working with the PPNC naturalist and other Lincoln Parks and Recreation Department employees, a preliminary list of potential short and midgrass prairie grasses, sedges and forbs was drafted. Because PPNC educates the public about prairie, Sedums purposely were eliminated. For the experiment, the list was reduced to 12 native species: six grasses, one sedge, and five forbs (Table 1). Other native species were also planted on the roof outside of the experimental plots. The plants were obtained from local suppliers or grown expressly for the experiment from a local, dry prairie seed source. In early June 2007, twelve, 1.83 m by 1.83 m (6 foot by 6 foot) plots were planted in an 8 by 8 grid of 64 plants as 72 cells dibble boarded into the media 0.2 m (8 inches) on center (Figure 2).

Five plants of twelve different species were each randomly assigned within the plots and four surplus plot corners were randomly assigned and planted to 2 each of prairie junegrass (Koleria macrantha) and hairy grama (Bouteloua hirsuta) (i.e., (5 X 12) + 4 = 64 plants/plot). Eight liters (2.1 gal) of slurry from a nearby Pioneers Park prairie remnant topsoil (Hedville sandy loam) was added as a potential source of mycorrhizae inoculant. Kemery and Dana (1995) have used a similar strategy to supply a native community of soil microbes (15).

Horta-Sorb hydrophilic polymer gel was incorporated at a rate of 1.2 g/ l³ of the media. At full water absorption this added just 25.22 kg/m² (5 lbs/ ft²) to the roof load.

Treatments were randomly assigned to the 12 rooftop plots as follows:

1) 3 Plots as the control consisted of 95% rooflite™ and 5% compost
2) 3 Plots as Horta-Sorb™ hydrophilic polymer gel added to rooflite™
3) 3 Plots slurried with filtered inoculant of prairie topsoil added to rooflite™
4) 3 Plots with both the Horta-Sorb™ and slurry inoculant added to rooflite™

Treatment plots were irrigated for the initial growing season June-October 2007 at a rate of about 2.54 cm (1.0 inches) per week above any rainfall. After October and until a period of sustained night frosts, the roof was irrigated at 1.25 cm (.50 inches) per week. Growth ratings were taken at the beginning of July, August, September and October using the criteria listed in Table 2. The October ratings represent the maximal growth for the season thus were selected to be analyzed for differences between treatments.
Figure 2. Planting 1.83 m by 1.83 m (6 foot by 6 foot) plots on the PPNC extensive green roof.

Table 1. Species Used in Extensive Green Roof Experiment

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Botanical Name</th>
<th>Type</th>
<th>Shortgrass</th>
<th>Midgrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. fringed sage</td>
<td>Artemisia frigida</td>
<td>Forb</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>2. Fendler aster</td>
<td>Aster fendleri</td>
<td>Forb</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>3. sideoats grama</td>
<td>Bouteloua curtipendula</td>
<td>Grass</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>4. blue grama</td>
<td>Bouteloua gracilis</td>
<td>Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. hairy grama</td>
<td>Bouteloua hirsuta</td>
<td>Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. sun sedge</td>
<td>Carex heliophila</td>
<td>Sedge</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>7. plains primrose</td>
<td>Calyophyllum serrulata</td>
<td>Forb</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>8. purple prairieclover</td>
<td>Dalea purpurea</td>
<td>Forb</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>9. Scribner’s panicum</td>
<td>Dicanthelium oliganthes</td>
<td>Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>var. scriberianum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. prairie junegrass</td>
<td>Koeleria macrantha</td>
<td>Grass</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>11. little bluestem</td>
<td>Schizachyrium scoparium</td>
<td>Grass</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>12. plains spiderwort</td>
<td>Tradescantia bracteata</td>
<td>Forb</td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>
Three random samples each of corner (surplus) grasses from inoculated plots and the uninoculated plots were collected, their roots were stained and checked under a microscope for mycorrhizae infection.

Table 2. Plant Growth Rating System

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Dead or missing plant</td>
</tr>
<tr>
<td>1</td>
<td>Live plant in poor condition; smaller than when planted; plant loose</td>
</tr>
<tr>
<td>2</td>
<td>Plant established but crown or top growth stagnant beyond plug;</td>
</tr>
<tr>
<td>3</td>
<td>Roots established, crown expanded up to 1 cm; or vigorous top growth</td>
</tr>
<tr>
<td>4</td>
<td>Roots established, crown expanded up to 2 cm; additional stems</td>
</tr>
<tr>
<td>5</td>
<td>Roots well-established, vigorous; crown&gt; 2 cm &lt; 6 cm beyond</td>
</tr>
<tr>
<td>6</td>
<td>Roots well-established, exceptional growth &amp; vigor; crown &gt; 6 cm &lt;10 cm</td>
</tr>
<tr>
<td>7</td>
<td>Crown expanding &gt;10 cm &lt; 16 cm</td>
</tr>
<tr>
<td>8</td>
<td>Plant expanding &gt;16 cm</td>
</tr>
</tbody>
</table>

Results

Growth ratings were analyzed as a split plot design using the Mixed procedure in SAS (26). Because treatments were applied to a treatment plot as a unit, the model used treatment plot as the error term when making treatment comparisons. Effects were considered significant at P<0.05. The data were examined using Bartlett's Test and found to have no significant differences for homogeneity of variance between plots of the same treatment (P = 0.778). ANOVA (Table 3) showed significant differences among the treatments, species, species X treatment interaction. Since the treatments showed significant differences they were examined further using LS Means (Table 4). Species testing will be reported elsewhere.

Table 3. Type 3 Tests of Fixed Effects Analysis of Variance (Significant at P<0.05)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Num DF</th>
<th>Den DF</th>
<th>F-Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>3</td>
<td>8</td>
<td>16.53</td>
<td>0.0009</td>
</tr>
<tr>
<td>Species</td>
<td>11</td>
<td>88</td>
<td>24.52</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Species*Treatment</td>
<td>33</td>
<td>88</td>
<td>1.92</td>
<td>0.0082</td>
</tr>
</tbody>
</table>

Table 4. Least Squares Means for Treatment Comparisons (Significant at P<0.05)

<table>
<thead>
<tr>
<th>Effect</th>
<th>trtm</th>
<th>trtm</th>
<th>Std. Est.</th>
<th>Error</th>
<th>DF</th>
<th>t-Value</th>
<th>P&gt; t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control v Inoc</td>
<td>1</td>
<td>2</td>
<td>-0.1167</td>
<td>0.08580</td>
<td>8</td>
<td>-1.36</td>
<td>0.2110</td>
</tr>
<tr>
<td>Control v Poly</td>
<td>1</td>
<td>3</td>
<td>-0.3444</td>
<td>0.08580</td>
<td>8</td>
<td>-4.01</td>
<td>0.0039</td>
</tr>
<tr>
<td>Control v Inoc*Poly</td>
<td>1</td>
<td>4</td>
<td>-0.5556</td>
<td>0.08580</td>
<td>8</td>
<td>-6.48</td>
<td>0.0002</td>
</tr>
<tr>
<td>Inoc v Poly</td>
<td>2</td>
<td>3</td>
<td>-0.2278</td>
<td>0.08580</td>
<td>8</td>
<td>-2.65</td>
<td>0.0290</td>
</tr>
<tr>
<td>Inoc v Inoc*Poly</td>
<td>2</td>
<td>4</td>
<td>-0.4389</td>
<td>0.08580</td>
<td>8</td>
<td>-5.12</td>
<td>0.0009</td>
</tr>
<tr>
<td>Poly v Inoc*Poly</td>
<td>3</td>
<td>4</td>
<td>-0.2111</td>
<td>0.08580</td>
<td>8</td>
<td>-2.46</td>
<td>0.0393</td>
</tr>
</tbody>
</table>

Control = rooflite™ only
Inoc = prairie soil slurry + rooflite™
Poly = polymer gel (Horta-sorb™) + rooflite™
Poly*Inoc = interaction

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Examining the significance of treatment LS Means at the 5% level, we find the control (Treatment 1) growth rating not significantly different from slurry of prairie soil (Treatment 2); the control growth rating is significantly lower than the Horta-Sorb™ gel alone (Treatment 3); control growth rating is significantly lower than the Horta-Sorb™ gel X inoculant interaction (Treatment 4) (Figure 3); the prairie soil inoculation (Treatment 2) growth rating is significantly lower than the Horta-Sorb™ alone (Treatment 3); the prairie soil inoculation (Treatment 2) growth rating is significantly lower than the Horta-Sorb™ gel X inoculation interaction (Treatment 4); the Horta-Sorb™ gel alone (Treatment 3) growth rating is significantly lower than the Horta-Sorb™ gel X inoculation interaction (Treatment 4).

Figure 3. Simple visual inspection reveals greener and more robust in plots 8 and 9 (Horta-Sorb™ X inoculant) than in plot 7 (control).
No statistical tests were made for abundance of mycorrhizae, but upon staining and visual inspection, roots from inoculated plots showed roughly three times the amount of root infection with vesicular-arbuscular mycorrhizae (VAM) than those from uninoculated plots.

Discussion

As well as supplying anchorage and water, media provides the nutrient foundation for sustaining green roof plantings. In this experiment the Horta-Sorb™ media modifications clearly improved growth and establishment for many of the species. This information may allow us to increase plant survival and growth during the short-term, establishment stage (lasting up to 3-5 years with prairie species) when moisture is critical for plant and root growth. During this phase, plantings may also need supplemental irrigation which gives roots needed time to fully expand and exploit media for nutrients, water and to fully penetrate and secure roof media. Ignoring this irrigation establishment factor led Monterusso et al (2005) to what I believe are erroneous conclusions that prairie plants (their “native taxa”) do not grow well on extensive green roofs without irrigation (21). In their study irrigation was applied for 1 and 1/3 growing seasons and abruptly terminated one month into the second summer when the maximum growth of warm-season is initiated. Prairie plants take several growing seasons to fully establish roots; their experiment could not have been better designed to insure prairie plant failure.

The hydrophilic polymer gel allows roots to access needed water and may obviate the need for structural water storage like the Hydrotech Gardenroof™ system. Such a finding would simplify installation and reduce cost of extensive green roofs and potentially even out the water availability on sloping green roofs. It is not known what the life of the Horta-Sorb will be on this extensive green roof. The clay-sized particle fraction is barred from most roof media specifications in order to reduce the likelihood of these smaller particles clogging root fabric barriers. Unfortunately the absence of clay and its hygroscopically held water further increases the droughty character of extensive green roof media. Coarsely-sized hydrophilic polymer gels such as used in this study allow rapid internal drainage while still supplying water to the root zone.

On the other hand, less striking are results of enhancing a plant’s growth by simply adding a more complete suite of organisms such as the microbes that produce mycorrhizae to the prairie plantings. Without also adding Horta-Sorb™ gel with the prairie slurry, the treatment of slurry alone did not significantly improve establishment and growth ratings above that of the control. The addition of the prairie slurry interacted with the Horta-Sorb™ to produce greater growth ratings than the gel alone. This likely comes both from the improved water acquisition, nutrient cycling, and nutrient uptake via mycorrhizae-rootlet. It is unknown whether or if gel supplies a more suitable physical niche for mycorrhizae.

The inoculation on the PPNC extensive green roof may need more time to become established and functioning regarding nutrient recycling. Kemery and Dana (2000) found in field trials with tallgrass prairie forb seedlings that growth and establishment under mycorrhizal inoculation were affected by the status of pre-existing site mycorrhizae, site fertility levels and transplant timing (15). It is unknown if microbial connections such as these are occurring with
Sedum. Even though the rate of root infection was low in the un-inoculated plots, the mere existence of mycorrhizae may have confounded the results. Mycorrhizae spores suitable for infecting prairie plants would no doubt be found in the ambient environment at the PPNC green roof since it is directly adjacent a 20-year old restored prairie with several hundred acres of additional virgin prairie nearby.

However, even given the lack of a significant difference in plant success with the inoculation alone, the corner plots showed that infection with VAM was higher in inoculated plots than those exposed to ambient spores only. Inoculation does appear to be a useful and relatively easy way to add VAM to the media plant interface.

Future research should look at the long-term growth and biotic maintenance of green roof plant assemblages and their media nutrient relationships, particularly the C:N ratio and the turnover rate of roots into organic matter and finally their decay and recycling into useable nutrients. Micronutrients, if unavailable and bound up in root or shoot biomass, or in organic matter un-recycled by the microbial community present in the media, may also eventually limit plant growth or life maintenance (16). Beyond water, nitrogen could become the next factor limiting green roof plant growth. Leguminous plants like purple prairielclove (Dalea purpurea) that in symbiosis with microbes (20) fix free atmospheric nitrogen should be part of all green roof plantings. However, they, too, may need microbial inoculation with Rhizobium bacteria.

More generally, green roof planting designers need to be explicit about whether tops or roots are more important. Sedums are used for their decorative tops and drought avoidance. Sedums simply do not have the same rooting potential as native prairie plants and may fail to hold soil in very windy locations. Priority in plant selection for extensive green roofs should be based on the following: 1) initial survivability, 2) growth (roots then tops), 3) long-term sustainability. Other aspects such as aesthetics and transpirative cooling are secondary priorities, because these benefits remain unrealized if the first three are met. I maintain that unseen roots are paramount in functioning as media anchorage. The prairie plant community is a useful analog here because perennial prairie plants mostly grow down before they grow up. Prairie plant communities are root extensive (25, 30). Prairie roots and their turnover into organic matter represent a major source of micro and macronutrients for plant maintenance and growth (16, 31). Plant ecologists have shown us that mature communities spend the majority of their energy on maintenance of life processes, not primary biomass production (29).

Net primary production associated with maximizing top growth is not always found in prairies. This reduced growth is observable, however, where plants slow their growth or just survive, for example on shallow soil over rock outcrops (Figure 1). (Also see the inspiration for Philips-Eco Enterprise Center extensive green roof 2006 Award of Excellence, Minneapolis, MN, by Kestrel Design (3)). While maximum top growth or flowering might be good for ranchers, lawn companies and bees, I maintain it is not functionally important for green roofs once they have become established and the media is protected against erosion by an extensive network of roots.

I suggest that designing green roof plant assemblages is in reality ecosystem design and a strategy is to provide, as fully as possible, a suite of species, plants, microbes and possibly...
invertebrates that maximizes functioning of biogeochemical processes. Providing this will help supply the needed functions (e.g., nutrient cycling) for maintenance of life processes that in turn maintain the root and plant coverage on green roof media. Green roof plantings need to mimic natural communities in order to be more sustainable in the environment in which they are situated and to conserve resources and labor.

Extensive green roofs should be approached and designed as landscape micro-ecosystems focusing upon:

- **structure** of the media and its biotic assemblage of plants, microbes and invertebrates
- **functional** strategies for sustainably supplying water and other nutrients that can be slowly reduced as the roof top ecosystem matures and finds equilibrium with its environmental context.
- **change** (i.e., disturbances, best management practices) that are sustainable and require minimal human and physical inputs

Management of green roof ecosystems in general can be judged against Aldo Leopold’s (1949) triumvirate of:

- **stability** in the face of environmental (e.g., drought) and anthropogenic (e.g. roof membrane replacement) changes
- **integrity** with surrounding local ecosystems and internal function
- **beauty** according to Leopold (1949) aesthetic enjoyment of landscape rests upon our knowledge and interaction with a particular place over time (17).

Providing a sense of place with healthy communities of plants (7) and connects humans with their physical environment (28).

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