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Fertilizer rate influences production scheduling of sedum-vegetated green roof mats

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ABSTRACT

To investigate the influence of controlled-release fertilizer application rates on summer-propagated sedum-vegetated green roof mat production timing, unfertilized sedum-vegetated mats (control) were compared to mats fertilized in August 2011 with Nutricote® Total 18–6–8 100 day controlled-release fertilizer at 5, 10, 15, 20, 25, and 35 g m^{-2} N. Fertilization rate influenced vegetative coverage, shoot height, inflorescence height and canopy area, leaf greenness and weed biomass. Mat production was completed late fall, following fertilization at ≥25 g m^{-2} N, while production was completed early the next spring, following fertilization at <25 g m^{-2} N. Although vegetative coverage of individual *Sedum* spp. changed over the course of the study, acceptable overall vegetative coverage was maintained following fertilization at ≥25 g m^{-2} N throughout the 2012 growing season. Production time ranged from 63 to 300 days following fertilization at 25 g m^{-2} N and the control, respectively. Fertilization rate influenced inflorescence characteristics of *Sedum* spp. and maximum leaf greenness was calculated to occur after fertilization with 25.6 g m^{-2} N. Therefore, by adjusting controlled-release fertilizer rates, production of green roof mats can be accelerated or slowed to meet production scheduling timelines.

1. Introduction

The area of installed North American green roofs has been increasing annually, with over one million more square feet of green roofs installed in 2012 than 2011 (Green Roofs for Healthy Cities, 2013). In 2012, 1.3 million square feet of green roofs were installed in the Washington DC metropolitan region alone (Green Roofs for Healthy Cities, 2013) with the main purpose of increasing building energy efficiency and increasing ecological functions in the urban environment (Getter et al., 2011; Oberndorfer et al., 2007). The high demand for green roof plants continues to provide opportunities for the horticultural industry to meet these needs. Extensive green roofs (i.e., sedum-vegetated green roof systems grown in ≤15 cm growing substrate; FLL, 2008) are most commonly installed (Green Roofs for Healthy Cities, 2013). *Sedum* spp. are used on green roofs because they can grow in shallow substrates (Durhman et al., 2007; Emilsson, 2008) and unfavorable environmental conditions (Durhman et al., 2006; Getter and Rowe, 2006; Wolf and Lundholm, 2008). Cuttings of some *Sedum* spp. shoots are often used to propagate green roof mats or applied in direct-to-roof plantings for multiple green roof systems in temperate climates. Between 12 and 18 months are often needed from cutting application to complete vegetation coverage on green roofs (Snodgrass and Snodgrass, 2006). The time needed to produce green roof systems (i.e., mats) in the nursery varies, and production completion is based on vegetative coverage (e.g., proportion coverage ≥0.8; FLL, 2008). Decreasing the time taken to produce marketable, cutting-propagated, sedum-vegetated green roof mats could help growers meet industry demands. Therefore, efficient production strategies are needed for sedum-vegetated green roof systems.

Sedum-vegetated green roof mats are commonly propagated in the spring; however, green roof installations in temperate climates are possible late into the fall. If production space becomes available late summer, growers may have the opportunity for late-summer propagated green roof mat production. Propagating and fertilizing *Sedum* spp. late summer can be considered unconventional, as slowing *Sedum* spp. growth can occur due to a transition from vegetative to reproductive growth or environmental stresses.

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However, previous research has indicated summer-propagation of sedum-vegetated green roof systems can be successful following appropriate fertilization (Clark and Zheng, 2014b).

Previous research has demonstrated that growing substrate fertility levels influence vegetative coverage, plant growth, and visual appeal of green roof systems (Clark and Zheng, 2012, 2013, 2014a,b; Emilsson et al., 2007; FLL, 2008; Retzlaff et al., 2009). Fertilizer-influenced *Sedum* spp. growth and vegetative coverage have decreased green roof module production timing in previous studies (Barker and Lubell, 2012; Clark and Zheng, 2014b). Production timing is primarily based on vegetative coverage, and is therefore, an important parameter to consider when adapting a green roof production fertilization plan.

Overall, to meet the industry demand for green roof plants, efficient green roof plant production, fertility programs and production scheduling need to be developed for individual climate regions. The objective of this study was to identify optimum controlled-release fertilizer application rates for summer-propagated sedum-vegetated green roof mats in the temperate North American climate.

2. Materials and methods

Field soil was graded to a slight slope in order to facilitate drainage at the green roof mat production site (Sedum Master, Princeton, ON; lat. 43°11′34″N, long. 80°35′56″W) on 21 July 2011. Three 1 m × 9 m replicate plot rows were installed, arranged as seven 1 m × 1 m fertilizer treatment plots per row and one additional border plot installed at each row end. A 1 m-wide unplanted strip was left between each row to provide access to the plots. Overall, 21 treatment plots were installed in a randomized complete block design with each row representing one block.

Plots were constructed in the following manner: a thin black plastic sheet was positioned on the ground under the plots for weed suppression, under a clear vapor barrier (6 mil Vapour Barrier; Polytarp Products, Toronto, ON) below a black plastic tangle mat (Bright Green Roofing and Living Walls LLC, Detroit, MI), which was topped with 2.5 cm of Sedum Master's standard green roof growing substrate. The substrate was comprised of 83% inorganic (i.e., sand, crushed brick) and 17% organic material (i.e., peat, compost, and coir), with 5.8% air-filled porosity, 0.81 g cm^{-3} dry bulk density, 62% volumetric water content, electrical conductivity (EC) of 4493 μS cm^{-1} and pH of 7.93. The substrate, subsampled at installation, contained 830 mg kg^{-1} total nitrogen (N), 810 mg kg^{-1} total phosphorus (P) and 2200 mg kg^{-1} total potassium (K). Total Kjeldahl N was determined using a classical Kjeldahl digestion and a Skalar segmented flow autoanalyzer, and NO_2^- and NO_3^- were determined using ion chromatography by SGS Agri-Food Laboratories, Guelph, ON. Both P and K were analyzed using a borate fusion-internal standard and X-ray fluorescence spectrometry method by SGS Laboratories, Lakefield, ON. The plant-available nutrient composition of the substrate was 283 mg kg^{-1} NO_3^-, 2.67 mg kg^{-1} P, and 263 mg kg^{-1} K (analyzed using a saturated paste extraction method by SGS Agri-Food Laboratories, Guelph, ON). Wooden dividers measuring 1 m × 2.5 cm × 2.5 cm were installed between plots to ensure plot separation. Cuttings of the following *Sedum* spp., with an average length of approximately 4 cm, were spread evenly by hand on top of the growing substrate at the standard commercial rate of 10.5 g · m^{-2}: *S. acre* L., *S. hybridum* L. 'Czar's Gold', *S. kamtschaticum* Fisch., *S. kamtschaticum* subsp. *ellacombeanum* (Praeger) R.T. Clausen, *S. rupestre* L. 'Blue Spruce', *S. rupestre* L. 'Angelina', *S. selskianum* Regel & Maack 'Goldilocks', *S. sexangulare* L., *S. spurium* M. Bieb., *S. spurium* M. Bieb. 'Dragon's Blood' and *S. spurium* M. Bieb. 'Tricolor'. After two weeks (5 Aug. 2011), additional cuttings were spread evenly on the plots to replace cuttings washed away during a strong rain storm. Following standard production practices, irrigation water (pH 8.0 ± 0.4; EC 233.0 ± 38.4 μS cm^{-1}) from an on-site catchment pond was applied to the field by overhead sprinklers as needed during the study (i.e., up to twice daily during the summer). On 31 Aug. 2011, once the cuttings were successfully rooted, three replications (n = 3) for each of seven fertilizer rate treatments were applied to plots, one replication per row. Plots were left unfertilized (i.e., 0 g m^{-2} N control), or fertilized by evenly spreading one of the following six fertilizer rate treatments: 5, 10, 15, 20, 25, 35 g m^{-2} N of Nutricote® Total 18–6–8 with minor nutrients 100 day controlled-release fertilizer (Plant Products Co. Ltd., Brampton, ON) per plot. Mean monthly air temperatures during the study ranged from 23.7 °C to 2.4 °C in July and January 2012, respectively.

Measurements were made monthly, between Aug. and Nov. 2011 and Mar. and July 2012, as environmental conditions permitted. Proportion vegetative coverage per plot was visually estimated by comparing vegetation-covered to non-covered areas, based on standard area references, by the same evaluator for the duration of the study to ensure consistency. Based on grower standards, plots were visually evaluated monthly, by the same evaluator to ensure consistency, to determine production completion. Vegetative coverage for individual *Sedum* spp. within plots was evaluated using the same method, and the same observer evaluated vegetative coverage at all time points to ensure consistency. Plant growth was evaluated by measuring vegetative shoot height, and inflorescence height and width in two perpendicular directions (i.e., d_1 and d_2) for three representative shoots and inflorescences per plot, for the three most prevalent species (i.e., *S. acre*, *S. spurium* and *S. spurium* 'Tricolor'). Inflorescence canopy area (A) was calculated by the following equation: $A = \pi \times 1/2\ d_1 \times 1/2\ d_2$. Leaf color of *S. acre* shoots was quantitatively evaluated as hue angle at three locations per plot using a colorimeter (Minolta CR-310; Minolta Camera Co. Ltd., Osaka, Japan). On 25 May 2012, all weeds were harvested from individual plots and dried at 70 °C ± 5 °C. Once a constant weight was achieved, weed dry weight per plot was measured. Above-ground dry weight of *Sedum* spp. was not evaluated since a post-production green roof installation was planned for treatment plots.

All data sets were analyzed using GraphPad Prism version 5.03 (GraphPad Software Inc., La Jolla, CA). A two-way repeated-measures ANOVA with a Bonferroni post-test was used to evaluate differences among treatments over time for normalized data of vegetative coverage, shoot height and leaf color. Regression analyses were used to relate leaf color, inflorescence height and canopy area, and weed dry weight to fertilizer rate and to estimate regression parameters for the best-fit regression model (linear or quadratic). Regression models for leaf color, inflorescence height and inflorescence canopy area were used to determine the optimal fertilizer rate for maximum greenness and inflorescence parameters and to estimate the fertilizer rate range at which 95% of the maximums would occur. A Pearson correlation was used to relate weed dry weight to vegetative coverage and fertilizer rate. All data were evaluated using a significance level of $P < 0.05$.

3. Results and discussion

3.1. Vegetative coverage per plot

The interaction between time and treatment influenced total vegetative coverage within plots during production ($P < 0.05$). Over time, total vegetative coverage increased in all treatments (Fig. 1). Although total vegetative coverage was not different among

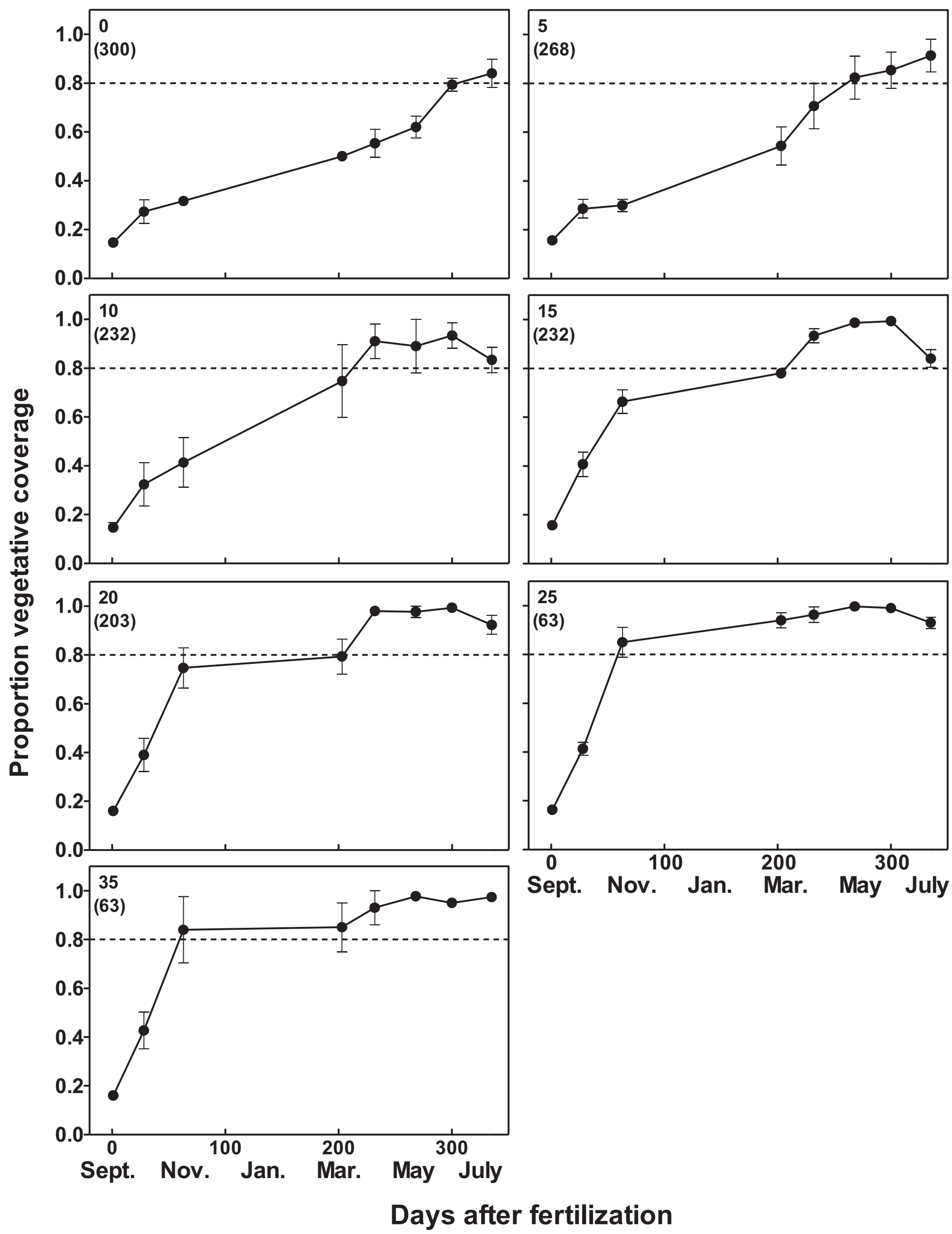

Fig. 1. Proportion vegetative coverage of sedum-vegetated green roof mats after fertilization on 31 Aug 2011 with 5, 10, 15, 20, 25 or 35 $g\,m^{-2}$ N, or unfertilized (control). Data are means ± SE ($n = 3$). Green roof mat production was considered complete on the date indicated in parentheses when proportion coverage ≥0.8 (dashed line) was observed.

treatments in Aug. or Sept., by Nov. 2011, vegetative coverage of the 15, 20, 25 and 35 treatments was larger than the 5, 10 and control treatments. The 25 and 35 treatments reached the target proportion coverage of 0.8 by Nov. 2011, while fertilizer treatments ≤20 reached the target coverage in 2012. The observed time from fertilization until the target coverage was reached ranged from 63 days in the 25 and 35 treatments, to 300 days in the control treatment. These results show that fertilization rate can be used to accelerate or slow *Sedum* spp. growth during green roof mat production. Similarly, during vegetative propagation of *Penniseum purpureum* cvs. Mott and Merkeron, the number of vegetative tillers increased with increasing fertilizer rate (Woodard and Prine, 1990). By using vegetative coverage timelines from the current study as a benchmark, growers can schedule fertilization to meet time-sensitive production goals. For example, applying ≥25 $g\,m^{-2}$ N to newly-propagated mats in August would complete mat production later that fall, while application of <25 $g\,m^{-2}$ N would result in production completion the following spring. Growers could achieve two production cycles of finished sedum-vegetated mats per year (i.e., early spring and early fall cutting application times), or make use of available production space, following late summer green roof mat propagation and fertilization at ≥25 $g\,m^{-2}$ N. Alternatively, fertilizing at rates <25 $g\,m^{-2}$ N would likely result in one green roof mat production cycle per year. In addition to the applied fertilizer rate, the nutrient composition of growing substrate components influences speed of vegetative coverage in installed sedum-vegetated green roof mats (Clark and Zheng, 2014a) and should also be considered during production scheduling. To the authors' knowledge, the current study is the first to identify the importance of adequate fertilization during sedum-vegetated green roof mat production.

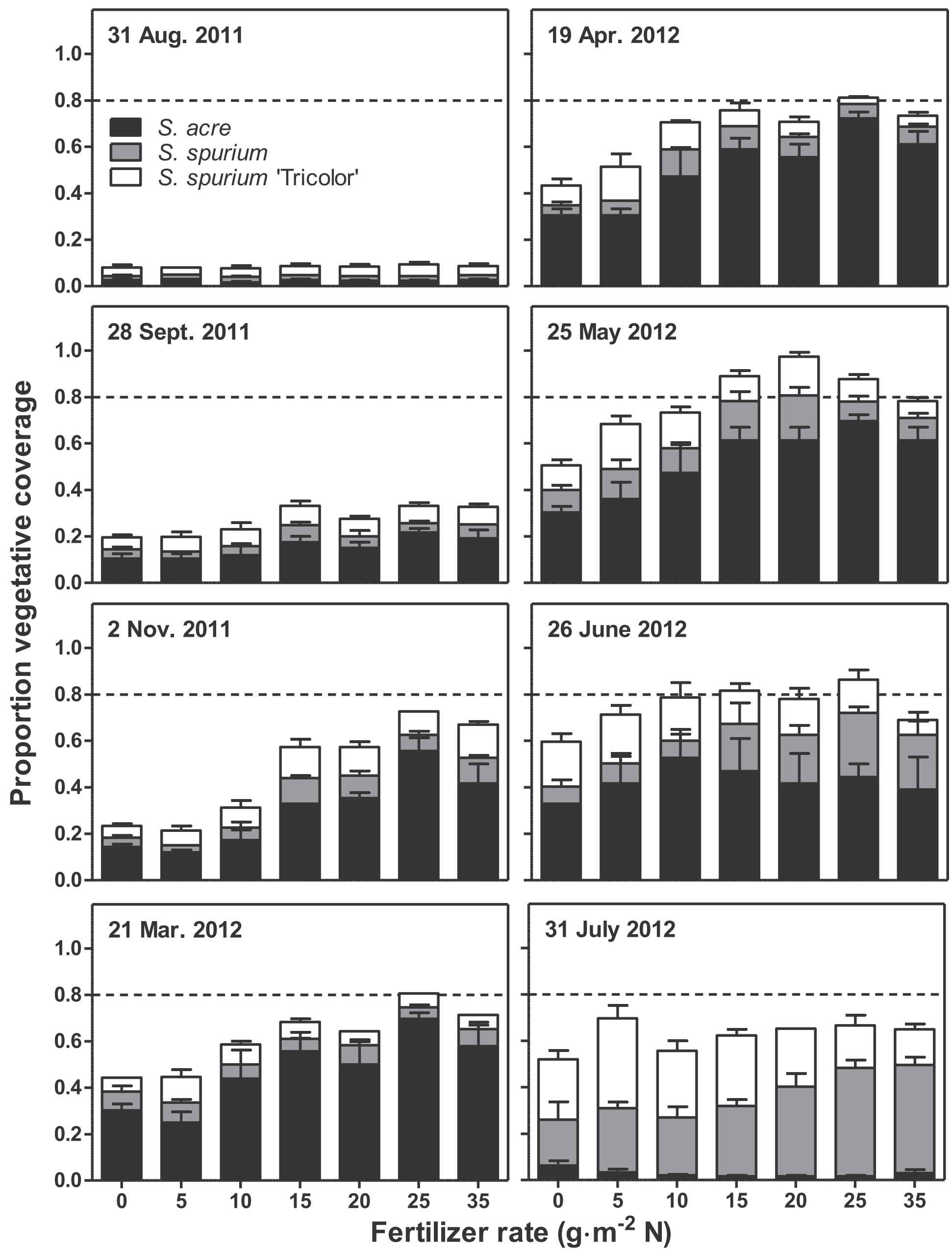

Fig. 2. Proportion vegetative coverage of individual *Sedum* spp. at time points during the 2011 and 2012 growing season following fertilization with 5, 10, 15, 20, 25, or 35 g m^{-2} N of controlled-release fertilizer, or unfertilized (control). Column sections represent mean values + SE (n = 3). Dashed lines represent the proportion coverage at which mat production was considered complete.

Vegetative coverage of *S. acre*, *S. spurium* and *S. spurium* 'Tricolor' was most prevalent within plots. Coverage of *S. acre* was influenced by the interaction of time and treatment, while *S. spurium* was only influenced by treatment ($P < 0.05$). *S. acre* coverage was greater in Nov. than Aug. 2011 for treatments ≥15, and greater from Mar. to June 2012 than Aug. 2011 for all treatments. (Fig. 2). Coverage of *S. spurium* was greater in June 2012 for treatments ≥15, and in July 2012 for all treatments, compared to Aug. 2011. *S. spurium* 'Tricolor' coverage was greater in Nov. than Aug. 2011 for the 15 and 35 treatments and greater for July 2012 than Aug. 2011 for all treatments. From June to July 2012, coverage of *S. spurium* and *S. spurium* 'Tricolor' increased for all but the 15, and all but the 25, 35 and control treatments, respectively, while *S. acre* coverage was reduced for all treatments during this time. This drastic shift in *S. acre* coverage was due to stem senescence following flowering, which likely provided space for *S. spurium* and *S. spurium* 'Tricolor' coverage to expand. Vegetative coverage of *S. kamtschaticum* subsp. *ellacombeanum* averaged <0.2 in all treatments at all time points except for the 30 and 35 treatments in July, 2012 (i.e., 0.2 in both treatments). For all other species combined (i.e., *S. hybridum* 'Czar's Gold', *S. kamtschaticum*, *S. rupestre* 'Blue Spruce', *S. rupestre* 'Angelina', *S. selskianum* 'Goldilocks', *S. sexangulare*, and *S. spurium* 'Dragon's Blood'), vegetative coverage averaged <0.2 in all treatments for the duration of the study.

The early vegetative coverage increase between 31 Aug. and 28 Sept. 2011 for *S. acre* may reflect the ability of this species to quickly establish, root and grow in response to fertilizer treatments. *S. acre* growth can be aggressive and is considered a weed in New

Zealand (Simcock, 2006). However, the vegetative coverage of *S. acre* was not long lasting (i.e., stems senesced between June and July 2012). Therefore, planting *S. acre* in combination with other *Sedum* spp. which grow well late summer (i.e., *S. spurium* and *S. spurium* 'Tricolor'), helped to maintain green roof mat vegetative coverage during *S. acre* late summer senescence. Although vegetative coverage of individual *Sedum* spp. changed over the course of the study, acceptable overall coverage was maintained for treatments ≥25. Therefore, planting green roof mats with an appropriate selection of *Sedum* spp., can contribute to long-lasting green roof coverage. In addition, planting appropriate *Sedum* spp. proportions and combinations (i.e., with complimenting morphologies and growth seasons) may prevent plant crowding, or incomplete coverage on green roofs during the growing season. Although previous research evaluated the influence of some *Sedum* spp. proportion combinations on green roof plot coverage over time (Barker and Lubell, 2012), such evaluations have not been found in the literature for *S. acre*. Further research evaluating *Sedum* spp. cutting proportions applied during green roof mat propagation should consider physiological changes of multiple species over time to determine ideal species proportions.

3.2. Plant growth

The interaction between time and treatment during production influenced shoot height of *S. acre*, and *S. spurium* 'Tricolor', while *S. spurium* shoot height was only influenced by time ($P < 0.05$). At fertilization on 31 Aug. 2011, mean shoot heights of *S. acre*, *S. spurium* and *S. spurium* 'Tricolor' were 3.8, 2.8 and 4.5 cm, respectively. For all *Sedum* spp. in all treatments, shoot height increased between Mar. and July 2012 (Fig. 3).

In addition to finished green roof mats, growers often produce *Sedum* spp. cuttings to sell or use for on-site propagation. Shoot height determines suitability of *Sedum* spp. growth for cutting harvest and an increased rate of shoot growth will permit an earlier cutting harvest date. In general, cutting lengths from 2.5 to 5 cm are often used for propagation, depending on the *Sedum* species (David Gilmore, personal communication). Therefore, an estimated minimum shoot height of 5.5 to 8 cm is generally appropriate to achieve both cutting harvest and leave 3 cm remaining on plants. By 28 Sept. 2011 (i.e., 28 days after fertilization), *S. acre* shoots in treatments ≥15 were taller than in all other treatments (i.e., 6.8 to 7.6 cm) and tall enough to be harvested as cuttings (i.e., ≥5.5 cm; Fig. 3). *S. acre* shoots in treatments ≥5 had shoots ≥5.5 cm tall by 2 Nov. 2011 (i.e., day 63), while shoots in the control were not ≥5.5 cm tall until 26 June 2012 (i.e., day 300). On 25 May 2012 (i.e., day 268), *S. spurium* and *S. spurium* 'Tricolor' shoots in treatments ≥10 and ≥5, respectively, were ≥5.5 cm tall. The delayed shoot growth for *S. spurium* and *S. spurium* 'Tricolor', compared to *S. acre*, may have been due to among-shoot competition, large leaves, or lateral branching, causing slow vertical growth for *S. spurium* and *S. spurium* 'Tricolor'. Since fertilization can assist growers in scheduling cutting harvests, growth rate for individual *Sedum* spp. should be considered when determining timelines for species-specific or mixed-species cutting production. We have not found literature suggesting *Sedum* spp. cutting harvest in combination with finished green roof mat production; however, pruning, clipping, or 'pinching' is a best management practice to increase density and vigor of ground cover plants (Klingeman et al., 2008). Decreasing the time taken to produce marketable sedum cuttings could help growers meet industry demands for green roof mats.

Excess fertilization can cause tall shoots to fall over (Clark and Zheng, 2013) or brown lower leaves to develop in sedum-vegetated green roof systems (Barker and Lubell, 2012; Clark and Zheng, 2014a). In treatments ≥15 and ≥10 by June and July 2012, respectively, some tall shoots (e.g., *S. acre*) had fallen over to cause gaps in vegetative coverage. In the current study, brown, desiccated tissue was not observed in the 5 or control treatments, but was observed in some 35 and 20 treatment plots by 25 May 2012 and for lower leaves in most treatments ≥10 by 26 June 2012. To explain similar observations of brown leaf tissue for *Sedum* spp., Barker and Lubell (2012) suggested decreased resilience of leaf tissue when grown under conditions of high fertility. In addition, dense growth, or leaf shading may have caused lower leaves to turn brown for *Sedum* spp. in the current study. Despite our observation of lower brown leaves developing in some treatment plots, the brown leaves were not clearly visible through a canopy of green upper leaves, and thus did not negatively affect overall appearance.

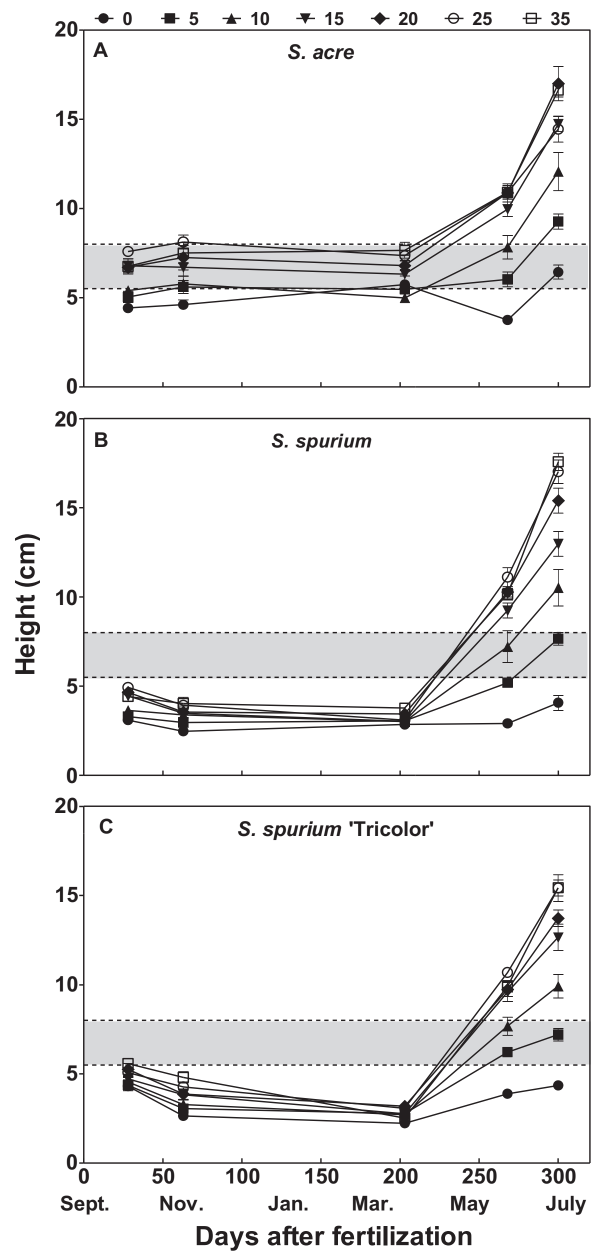

Fig. 3. Shoot height of *Sedum acre*, *S. spurium* and *S. spurium* 'Tricolor' planted in green roof mats following fertilization on 31 Aug. 2011 with 5, 10, 15, 20, 25 or 35 g m^{-2} N, or unfertilized (control). Data are means ± SE ($n = 9$). Cutting harvest can occur at shoot heights between 5.5 and 8 cm, indicated by the dashed lines and shaded region.

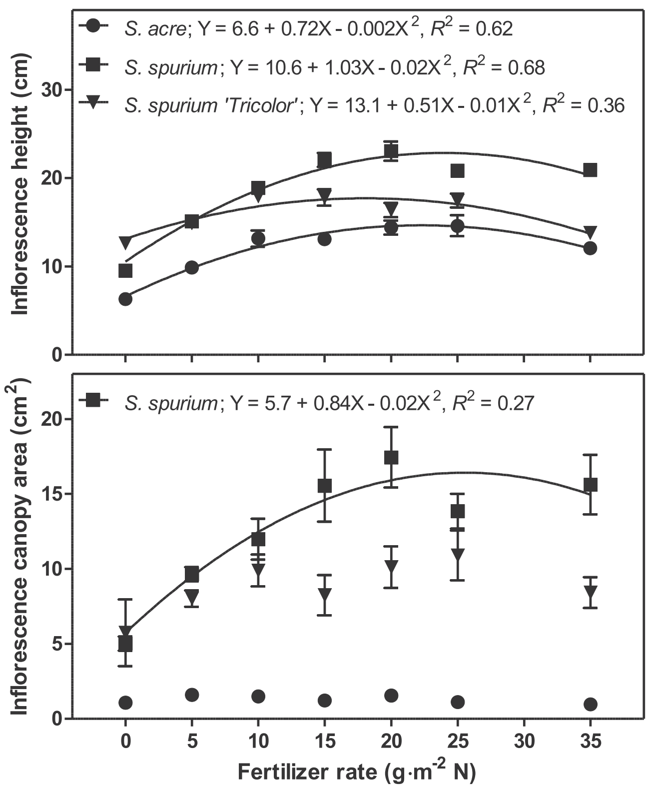

Fig. 4. Inflorescence height and canopy area in July 2012 following fertilization with 5, 10, 15, 20, 25, or 35 g m^{-2} N of controlled-release fertilizer, or unfertilized (control). Data are means ± SE (n = 9). Where fertilizer rate effect was significant (P < 0.05), an equation and a line indicates the calculated regression.

However, when tall shoots fell over, visible lower brown leaves reduced overall appearance. For this green roof mat system, determining the balance between fertilizer rate and duration of growth is needed to prevent excess shoot height during production. If mats had been shipped and installed once vegetative coverage was sufficient (i.e., proportion coverage of 0.8), excess shoot growth may not have occurred. Therefore, one possible solution for excess shoot height during production could simply be shipping finished mats before shoots become overgrown. When installed on green roofs having deeper substrates than the depth during production, plants will likely favor root growth over shoot growth during establishment (Burdett et al., 1984) to maintain appropriate shoot heights. Alternatively, if mats remain in production fields past the ideal shipping date, tall shoots could be clipped, mats could be allowed to re-grow, and the cuttings could be sold or used on-farm for *Sedum* spp. propagation. Further research is needed to determine optimum fertilizer rates to ensure appropriate establishment of sedum-vegetated green roof mats following rooftop installations, with or without a prior cutting harvest.

3.3. Inflorescence growth

Inflorescence height responded quadratically to fertilizer rate for *S. acre*, *S. spurium* and *S. spurium* 'Tricolor', while only *S. spurium* inflorescence canopy area showed the same response (Fig. 4). The maximum inflorescence height and 95% of the maximum was calculated to occur at fertilizer rates of 22.2 ± 6.7, 24.0 ± 7.3 and 18.1 ± 8.0 g m^{-2} N for *S. acre*, *S. spurium* and *S. spurium* 'Tricolor', respectively, and 21.8 ± 7.3 g m^{-2} N on average for all three species. The maximum and 95% of maximum for inflorescence canopy area was calculated to occur at 25.5 ± 7.1 g m^{-2} N for *S. spurium*. Similar

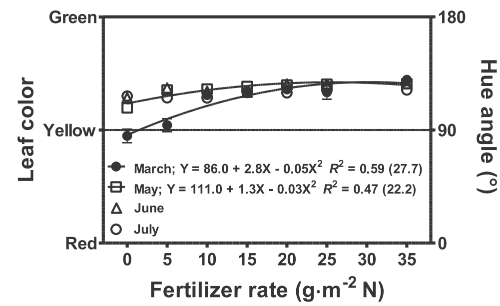

Fig. 5. Regression analyses of the effect of controlled-release fertilizer rate on *Sedum acre* leaf color in green roof modules, as measured by hue angle, between March and July 2012. Data are means ± SE (n = 9). Where fertilizer rate effect was significant (P < 0.05), an equation and a line indicates the calculated regression. The fertilizer rate calculated to produce maximum leaf greenness at each time point is given in parentheses.

to observations by Clark and Zheng (2012), these results confirm the influence of fertilizer rate on *Sedum* spp. flowering performance in green roof systems. Upon installation, flowering performance of green roof plants increases pollinator habitat in urban areas, adding ecologically-important foraging resources to green roof benefits (Tonietto et al., 2011).

3.4. Leaf color

Fertilizer treatment influenced leaf color of *S. acre* shoots during production from 21 Mar. to 31 July 2012 (P < 0.05). Leaves were greener in July than Mar. 2012 for both the 5 and control treatments (Fig. 5). On 21 Mar. 2012, leaves in treatments ≥10 were greener than in the 5 treatment, while on 31 July 2012, leaves in the 25 and 35 treatments were greener than in the 5, 10, and control treatments. Considering all time points, the mean overall maximum leaf greenness was calculated to occur after fertilization with 25.6 g m^{-2} N. Similarly, Clark and Zheng (2014b) identified that fertilization at 25.2 g m^{-2} N would result in maximum leaf greenness in a sedum-vegetated green roof module production system. Since *Sedum* spp. leaf color influences the visual appeal of green roofs (Clark and Zheng, 2012), growers may consider leaf color as a characteristic to evaluate when determining production completion.

3.5. Weed growth

Dry weight of weeds harvested per plot on 25 May 2012 was not influenced by vegetative coverage in May (r = 0.27), contrary to suggestions by Getter and Rowe (2006), but weed dry weight increased with increasing fertilizer rate (P < 0.05; Fig. 6). Similarly, Emilsson

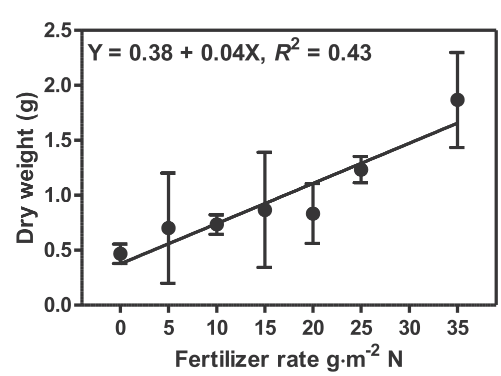

Fig. 6. Regression analysis of the effect of controlled-release fertilizer rate on weed dry weight. Data are means ± SE (n = 3). Where fertilizer rate effect was significant (P < 0.05), an equation and a line indicates the calculated regression.

and Rolf (2005) suggest green roof growing systems with high nutrient holding capacities may have high levels of weed establishment. However, in the current study, after weed removal in May 2012, few weeds were observed in any plot. Therefore, after investing the time to weed production fields only once, high levels of weed establishment are not likely to re-occur in this green roof system.

4. Conclusions

Sedum-vegetated green roof mats propagated in July and fertilized in Aug. 2011 increased in vegetative coverage relative to fertilizer rate. By Nov. 2011, fertilization at 25 and 35 $g\,m^{-2}$ N produced green roof mats with a proportion vegetative coverage $\geq$0.8 (i.e., the target threshold for production completion). Since coverage of individual *Sedum* spp. changed over the course of the growing season, producing green roof mats with an appropriate selection of *Sedum* spp. provided long-lasting coverage and visual appeal. Shoot heights of *S. acre* in Sept. 2011, and *S. spurium* and *S. spurium* 'Tricolor' in May 2012 in treatments $\geq$15, $\geq$10 and $\geq$5, respectively, were $\geq$5.5 cm tall and could be harvested for cuttings. Fertilizer rate influenced inflorescence height of individual *Sedum* spp. and inflorescence canopy area of *S. spurium*. Maximum leaf greenness was calculated to occur after fertilization with 25.6 $g\,m^{-2}$ N. Overall, due to quick vegetative coverage, shoot and inflorescence growth and leaf greenness, fertilization at 25 $g\,m^{-2}$ N in August is recommended to efficiently produce green roof mats in the fall. For production completion the following spring, fertilization at rates <25 $g\,m^{-2}$ N are recommended when using green roof growing substrates similar to the one used in this study. Therefore, green roof mat production timelines can be adjusted using fertilizer rates, according to grower priorities, to accelerate or slow production of sedum-vegetated mats to meet production schedules for green roof installations.

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