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Clover (*Trifolium* spp.) Inclusion in Kentucky Bluegrass (*Poa pratensis*) Lawns

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Abstract. **Historically, white clover (*Trifolium repens*) seed was included in turfgrass seed mixtures to provide biodiversity and nitrogen (N) to lawns. White clover dicultures have been studied recently for inclusion in both warm- and cool-season turfgrasses, with the goals of reducing fertilizer applications and providing pollinator forage in lawns; however, other clovers have not been as widely researched in turfgrass. The objectives of this study were to evaluate 1) if white, strawberry (*T. fragiferum*), crimson (*T. incarnatum*), and rose (*T. hirtum*) clovers can persist in dicultures with Kentucky bluegrass (*Poa pratensis*); 2) if clover inclusion in dicultures impacts broadleaf weed cover; and 3) if low levels of N fertilization impact clover persistence or quality of clover–bluegrass dicultures. Kentucky bluegrass was grown as a monoculture or as a diculture with each of the four clover species. Each mono- or diculture was then treated with a low rate of N fertilizer (48.8 kg·ha^{-1} N) or no N fertilizer to determine quality and percentage of grass, clover, or weed and bare-soil cover. Dicultures contained similar or less weed and bare-soil cover, and maintained similar or greater quality compared with bluegrass monocultures, indicating clover and Kentucky bluegrass dicultures are suitable alternatives to Kentucky bluegrass monoculture lawns, and can potentially lead to reduced fertilizer and pesticide requirements. Fertilizer generally had no effect on cover, likely because of the low rates of N applied.**

Nitrogen (N) fertilization is important for maintaining high-quality turf because it promotes a dark-green color and turfgrass growth and density (Duble 1996). A survey of 141 homeowners across seven US metropolitan areas indicated that 62% of those lawns receive some sort of supplemental fertilizer applications (Wheeler et al. 2017). Incorporating legumes into turfgrass fell out of practice because the dark-green, weed-free monoculture lawn became a symbol of class status and because herbicides became more readily available (Harris et al. 2013); however, focus on reduced inputs and improved ecosystem services of turfgrass, such as heterogeneous mixtures that persist under varied management, has become more common in recent years (Braun et al. 2023; Ignatieva et al. 2020). If N-fixing legumes, such as clover, can be incorporated into lawn systems to provide even a portion of the N required to maintain acceptable turfgrass quality, fertilizer inputs to turfgrass could be reduced.

Nitrogen application may affect clover persistence in turfgrass negatively. For example, in a 2-year study of mixed cool-season grass and microclover stands, Bigelow et al. (2022) reported that although all mixed stands had reductions in clover populations over time, greater reductions were observed in fertilized stands receiving 98 kg·ha^{-1} N annually compared with unfertilized stands. Unfertilized white clover and grass mixtures can maintain similar green cover as fertilized turfgrass (Macke 2016). Clover and grass mixtures can also use greater amounts of soil-derived N than pure stands of either grass or clover when fertilized with various rates of N fertilizer (3–72 kg·ha^{-1} N) (Høgh-Jensen and Schjoerring 1997). In addition, clover and grass mixtures can achieve greater stand quality than unfertilized pure turfgrass stands and equal quality to that of fertilized pure turfgrass stands (Macke 2016), can demonstrate improved growth (Elgersma et al. 1998; Høgh-Jensen and Schjoerring 1997), can provide pollinator forage (Boyle et al. 2020; Larson et al. 2014; Macke 2016; Potter et al. 2021), and can support similar numbers of predatory arthropods and earthworms as grass or clover monocultures (Potter et al. 2021).

A majority of research on clover inclusion in turfgrass focuses on white clovers, including more compact white clover varieties known collectively as microclovers. White clover is a perennial, stoloniferous clover that produces a dark-green color throughout the summer and can withstand regular mowing. White clover is best adapted to cool, wet conditions, but can persist in sandy, dry soils if irrigated and fertilized (St. John and Ogle 2008). Microclovers' smaller leaves blend well with turfgrass stands, and microclovers can persist in cool-season turfgrass (Bigelow et al. 2022) and can achieve greater stand quality than unfertilized turf-only stands and similar quality to fertilized turf-only stands (Bigelow et al. 2022). White clover can also persist in bermudagrass (*Cynodon* spp.) (Boyle et al. 2020; McCurdy et al. 2013b) and hard fescue (*Festuca brevipila*) (Lane et al. 2019), and can also establish in perennial ryegrass (*Lolium perenne*), although persistence over time can vary depending on time of year, climate, maintenance, and cultivar (Elgersma et al. 1998). Both 'Dutch' white clover and microclover can also be established in tall fescue (*Schedonorus arundinaceus* Schreb.) (Potter et al. 2021; Sparks et al. 2015), Kentucky bluegrass (*Poa pratensis* L.) (Sparks et al. 2015), and mixed cool-season turfgrasses (Hejduk and Kvasnovský 2014).

Although white clover can establish and persist in combination with turfgrasses, composition of clover and grass mixtures can vary over time as a result of changes in environmental conditions and management (Bigelow et al. 2022; Boyle et al. 2020; McCurdy et al. 2014). Although this change in mixture composition may initially seem undesirable in turfgrass, this "insurance" could be beneficial in lawns and low-maintenance turfgrass. When environmental conditions are not favorable for turfgrass growth, clover may be used to maintain an acceptable level of green cover. Conversely, turfgrass may dominate and provide acceptable levels of green cover when conditions do not favor clover growth. Clover species other than white clover have not been as widely tested for turfgrass mixtures; however, because establishment and persistence vary

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with environmental conditions and management, clover species other than white clover may be better adapted for lawns in the arid western United States where heat, cold, and drought may limit the long-term success of white clover.

Strawberry clover (*Trifolium fragiferum*) is another prostrate, stoloniferous perennial clover that is well adapted to close, continuous grazing (Townsend 1985). Strawberry clover is the most saline soil-tolerant, commercially available clover; can tolerate short-term drought; can persist better than white clover in hot, dry conditions; and is generally considered to be more hardy than white clover (Oregon State University Forage Information System 2018; St. John et al. 2010). For example, strawberry clover can maintain a greater leaf water status, photosynthesis rate, and transpiration rate under drought conditions than white clover (Hofmann et al. 2007). Strawberry clover can establish well with bermudagrass and cool-season grasses, although persistence can vary (Boyle et al. 2020; Cook 2005; Gibeault and Leonard 1987). Bermudagrass and Kentucky bluegrass mixed with strawberry clover has as a good or better general appearance and green color as that associated with turfgrass monostands (Baltensperger and Gaussoin 1985). Strawberry clover is, however, more susceptible to root and crown rot than white clover (Townsend 1985).

Crimson clover (*Trifolium incarnatum*) is an erect-growing winter or summer annual commonly used as a cover crop in vineyards, orchards, and in rotation with field crops, likely a result, in part, of its efficacy at suppressing weeds (Knight 1985; Oregon State University Forage Information System 2018; Young-Mathews 2013). Crimson clover can tolerate poor-quality soil better than other clover species, and persists better and produces more biomass than most other clovers under cool temperatures (Young-Mathews 2013); however, crimson clover does not usually tolerate drought or extreme heat or cold (National Resource Conservation Service 2009; Oregon State University Forage Information System 2018). Crimson clover is reported to be more disease and nematode resistant than other clovers, but is susceptible to crown and root rot in cool, wet conditions (Young-Mathews 2013). Both diseases can be promoted in thick stands, but can be prevented by removing foliage (Young-Mathews 2013)—a common practice in routinely mown turf. Crimson clover provides forage for honeybees, native bees, and wildlife, and can host beneficial parasitic insects (Young-Mathews 2013). Crimson clover grows rapidly in fall and early spring and can extend the growing season further into the fall than many cool-season grasses under forage conditions (Knight 1985); similar trends may be observed in turfgrass stands.

Rose clover (*Trifolium hirtum*) is a semi-erect winter annual used in California rangelands (Love 1985). Rose clover is commonly used in soils that are too dry for other clovers or too acidic for other legumes such as medics (*Medicago* spp.) (Oregon State University Forage Information System 2018). Rose clover is adapted to areas receiving between 400 and 750 mm of annual precipitation, is more drought tolerant than subterranean clover (*Trifolium subterraneum*) as a result of a deeper rooting habit, with roots reaching up to 2 m deep (Love 1985; Oregon State University Forage Information System 2018). Rose clover has been established successfully in bermudagrass (Evers 1995) and Old World bluestem (*Bothriochloa ischaemum*) (Volesky et al. 1996) pastures. Because it is well adapted to low-moisture conditions and has a deep root system, rose clover may be able to persist better in the hot and dry summers typical of the arid West, when Kentucky bluegrass is drought and heat stressed, although cold winters may limit long-term success.

Mowing tolerance is an important consideration when managing mixed lawn stands. White, strawberry, crimson, and rose clovers are all adapted to grazing, indicating they may persist in mown turfgrass. White, strawberry, and rose clovers perform best under continuous grazing (a possible proxy for mowing), but crimson clover is better adapted to "rotational" grazing (Van Keuren and Hoveland 1985) and may not perform as well under the regular mowing schedule common in turfgrass settings.

It is unclear whether these clover species will persist in Kentucky bluegrass grown in the arid West, how inclusion of these species might impact N transfer and resistance to weed invasion, or how these mixtures might respond to N fertilization. Therefore, the objectives of this study were to evaluate 1) if rose, crimson, strawberry, and white clovers can persist in dicultures with Kentucky bluegrass; 2) if clover inclusion in dicultures impacts broadleaf weed encroachment into turf; and 3) if low levels of N fertilization impact clover persistence or quality of clover–bluegrass dicultures.

Materials and Methods

Study sites. This study was conducted at the Utah Agricultural Experiment Station Greenville Research Farm in Logan, UT, USA (Logan) and the Utah State University Botanical Center in Kaysville, UT, USA (Kaysville). Logan soil was a Millville silt loam (coarse-silty, carbonatic, mesic Typic Haploxerolls); Kaysville soil was a Kidman fine sandy loam (coarse-loamy, mixed, superactive, mesic Calcic Haploxerolls).

Experimental design and treatments. The five plant treatments included 2.3 m^2 plots of a monoculture of Kentucky bluegrass ('Diva' seeded at 146.5 $kg \cdot ha^{-1}$ or blended Kentucky bluegrass sod in 2019 and 2020, respectively) or dicultures of Kentucky bluegrass and 'Dutch' white clover, 'Palestine' strawberry clover, 'Dixie' crimson clover, or rose clover ('Hykon' or an unnamed variety in 2019 and 2020, respectively). Clover seeds used in our study varied in size, so seeding rates based on percentage by weight would have resulted in varying numbers of clover plants, depending on species. Instead, seeding rates used in our study were based on white clover seeding rates used in a previous turf–white clover lawn mix study (5 $kg \cdot ha^{-1}$ white clover seed) (McCurdy et al. 2013b). This is equivalent to ~755 clover seed/m^2. Plots were irrigated as needed to prevent drought stress.

Each monoculture or diculture included an additional treatment factor of fertilization, with 0 (unfertilized) or 48.8 $kg \cdot ha^{-1}$ supplemental N (fertilized) applied in the fall (44–0–0; The Andersons Inc., Maumee, OH, USA). Because of issues outlined next, trials did not extend into the spring season.

2019 Study. In 2019, each study site was used as a replicate, with a randomized complete block design with four replications at each site. Plots were seeded into bare soil 6 Jun 2019 at the Logan and Kaysville locations. Plots were mowed weekly at a 7.6-cm height of cut, with clippings returned, starting 9 Aug and 16 Aug at Logan and Kaysville, respectively. To observe the competitive ability of the treatments, no pesticides were applied during the study. Nitrogen treatments were applied to their respective plots on 10 Sep.

A 1 × 1-m quadrat with 10-cm intersect spacing was used to evaluate percentage grass, clover, and broadleaf weed or bare-soil composition once per month in September and October. If multiple cover types were present at an intersection, the taller or dominant cover type was recorded. Any weeds present were also identified. Digital images were taken weekly using a portable, enclosed light box (0.4 m^2) to provide a consistent, objective light source (Karcher and Richardson 2013). Images were evaluated for overall quality using Turf Analyzer software (Turf Analyzer Green Research Services, LLC, Fayetteville, AR, USA), a program that analyzes photos for coverage, dark-green color index, density, and uniformity, and assigns a ranking using a 1- to 9-point scale, where plots ranking 1 point are dead or dormant and plots ranking 9 points are considered ideal turfgrass quality (Skogley and Sawyer 1992). Plots ranking 6 points or more were deemed acceptable, whereas plots scoring less than 6 points were deemed unacceptable.

2020 Study. Because of the COVID-19 pandemic, as well as irrigation restrictions at the Kaysville site, the trial was restarted in 2020 at a new plot location at the Logan site. The 2020 study area consisted of an established Kentucky bluegrass blend. The site was prepared for clover planting with a joint application of triclopyr, fluroxypyr, and 2-methyl-4-chlorophenoxyacetic acid (MCPA) (Battleship III; Helena Agri-Enterprises, LLC, Collierville, TN, USA) and 2,4-Dichlorophenoxyacetic acid (2,4-D), 2-ethylhexyl ester, carfentrazone-ethyl, dicamba, and mecoprop-P (SpeedZone; PBI Gordon Corp., Shawnee, KS, USA) on 9 Apr. On 30 Apr, the site was overmowed to 1.3 cm and clippings were removed to enhance clover seed-to-soil contact and light penetration (McCurdy et al. 2013b; Sparks et al. 2015).

Clovers were seeded 4 May and were irrigated as needed to prevent stress. Monoculture and diculture plots were 2.3 m^2 in size. Six weeks after seeding, mowing was initiated at an 8.9-cm height of cut, with clippings returned. Mowing was continued on a weekly basis during the growing season (15 Jun–30 Oct). To observe the competitive ability of the treatments, no herbicides were applied after clover was seeded. Nitrogen treatment rates were the same as those used in the 2019 trial [unfertilized or 48.8 $kg \cdot ha^{-1}$ supplemental N (44–0–0; The Andersons Inc.)] and were applied 13 Oct. Percent cover was measured using the quadrat method (outlined earlier) on a weekly basis, July through October.

Statistical analyses. Cover percentage data from 2019 and 2020 were averaged over their respective years, and the logits of the yearly averages were analyzed by a mixed model in which species, N, and cover type, and their interactions were fixed effects, and locations and blocks within each location were random effects. The correlations resulting from repeated measurements of the three cover types (grass, clover, and weed/bare-soil cover) on each plot were included with an unrestricted variance–covariance structure in the mixed model. The analysis was performed separately for each year because of differences in establishment method, location, management, and frequency of observation. The GLIMMIX procedure in SAS v. 9.4 (SAS Institute, Cary, NC, USA) was used to implement the mixed model, and percentages of cover for each cover type under each treatment were estimated by least squares means and corresponding standard errors. Pairwise comparisons among the treatments were conducted with Tukey-Kramer's method, adjusting for multiplicity. Significance was predefined at the 0.05 level. Results were visualized in RStudio v. 2023.12.1 (PBC, Boston, MA, USA).

Results and Discussion

2019 Cover composition. There was no significant effect of N fertilization on cover type in the 2019 trial. This is likely a result of the single application of the low rate of N that was applied. Although 48.8 $kg \cdot ha^{-1}$ N is a typical low-fertility application rate for fall fertilization of cool-season lawns in Utah, USA, it is commonly accompanied by spring fertilization, for a yearly fertilization rate of 97.6 $kg \cdot ha^{-1}$ N annually (Kopp and Johnson 2011). These plots did not receive a spring fertilizer application because of the termination of the study at these locations after the Fall 2019 season. Long-term fertilization may impact cover composition of mixed Kentucky bluegrass and clover dicultures over time, but more research is needed to determine the rate and frequency of fertilizer application at which these differences may be observed.

Grass cover of bluegrass monocultures was significantly greater than dicultures at both N fertilization levels in 2019 (Fig. 1). Because bluegrass monocultures and dicultures were seeded with similar amounts of bluegrass seed, this difference is likely a result of competition from clover seed germinating and establishing alongside, or before, the bluegrass seed in dicultures. Clovers were observed germinating within 6 to 8 d, whereas Kentucky bluegrass is generally slower to germinate and establish. When unfertilized, grass cover of dicultures was not significantly different; however, when fertilized, white clover dicultures had significantly less grass cover than strawberry and rose clover dicultures (Fig. 1).

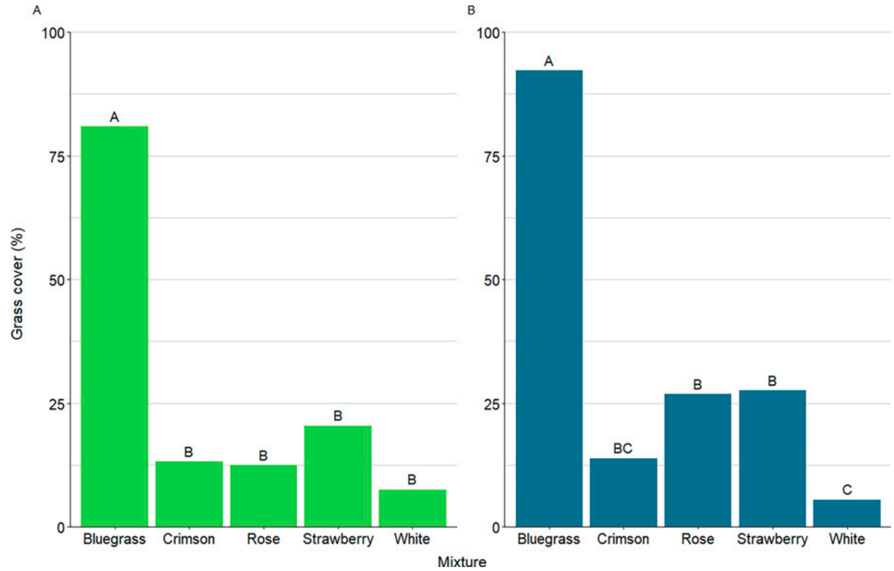

Fig. 1. Mean percentage of grass cover for (**A**) unfertilized and (**B**) fertilized (48.8 $kg \cdot ha^{-1}$ N) Kentucky bluegrass monocultures or dicultures of Kentucky bluegrass grown with crimson, rose, strawberry, or white clover in 2019. Bars within a fertilization treatment with different letters indicate significantly different cover ($P \leq 0.05$).

Clover cover of unfertilized and fertilized plots was significantly greater in all dicultures compared with bluegrass monocultures in 2019 (Fig. 2). This is to be expected because no clover was included in bluegrass monocultures when seeding, and any clover identified in bluegrass monocultures was recorded as a weed, if present. When fertilized, white clover maintained significantly greater clover cover than other dicultures (Fig. 2).

Bluegrass monocultures at both fertilization levels maintained significantly greater weed and bare-soil cover compared with all dicultures in 2019 (Fig. 3). Many plots at the Kaysville location retained some bare-soil cover throughout the study period. This is possibly a result, in part, of the water status of the plots. Kaysville was irrigated using agricultural hand lines, and plots were watered for 30 min or more one to three times per week. Ponded water was often observed

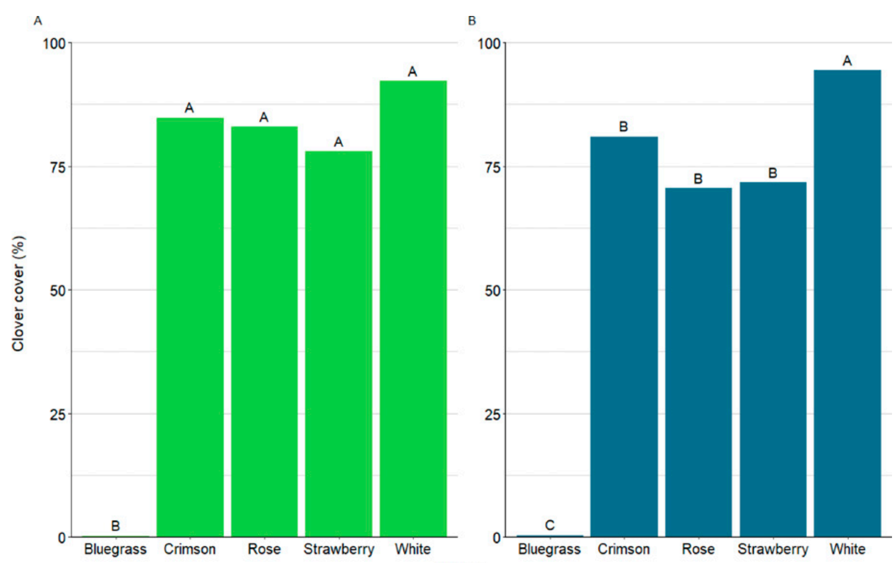

Fig. 2. Mean percentage of clover cover for (**A**) unfertilized and (**B**) fertilized (48.8 $kg \cdot ha^{-1}$ N) Kentucky bluegrass monocultures or dicultures of Kentucky bluegrass grown with crimson, rose, strawberry, or white clover in 2019. Bars within a fertilization treatment with different letters are significantly different ($P \leq 0.05$).

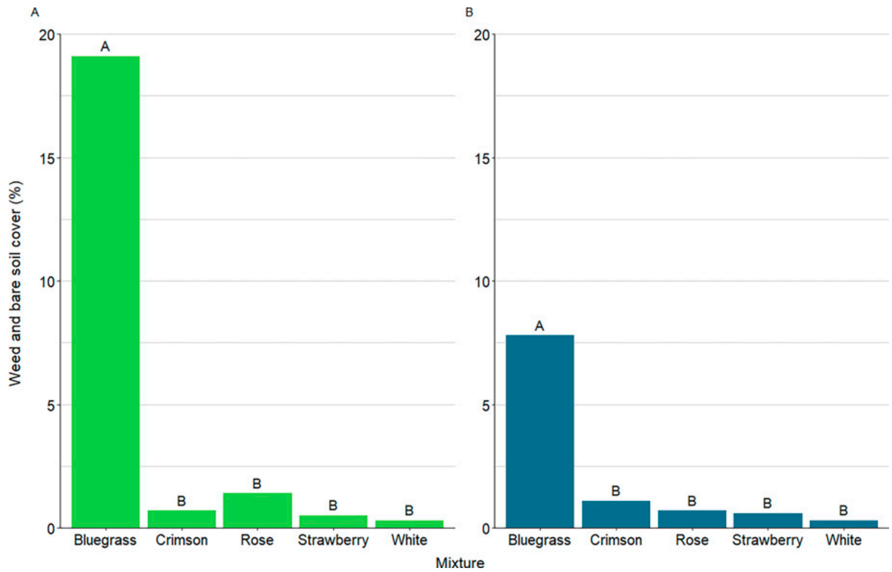

Fig. 3. Mean percentage of weed and bare-soil cover for (**A**) unfertilized and (**B**) fertilized (48. kg·ha^{-1} N) Kentucky bluegrass monocultures or dicultures of Kentucky bluegrass grown with crimson, rose, strawberry, or white clover in 2019. Bars within a fertilization treatment with different letters are significantly different ($P \leq 0.05$).

postirrigation. This may have washed away seed before it could become established, or plots may have been unsuitably wet during the establishment period for successful grass or clover germination. Weeds identified across plots at the Kaysville location included bindweed (*Convolvulus* spp.), mallow (*Malva* spp.), dandelion (*Taraxacum officinale*), lambsquarters (*Chenopodium album*), pigweed (*Amaranthus* spp.), witchgrass (*Panicum capillare*), foxtail (*Setaria* spp.), and unidentified weeds. Weeds at the Logan location included black medic (*Medicago lupulina*), thistle (*Cirsium* spp.), prostrate knotweed (*Polygonum aviculare*), dandelions, and pigweed, along with unidentified weeds.

2020 Cover composition. Under both N treatments in 2020, clover cover was significantly less in the Kentucky bluegrass monocultures compared with all dicultures (Fig. 4). This is to be expected because no clover was seeded into the Kentucky bluegrass monocultures, and any clover that was present was counted as weed cover when quadrant counts were conducted. Nitrogen fertilization was also not significant in 2020, again likely a result of the low rates applied (48.8 kg·ha^{-1} N). In 2020, when no N was applied, clover cover in strawberry clover dicultures was significantly less than crimson or white clover dicultures, but was not significantly different from clover cover in rose clover dicultures (Fig. 4).

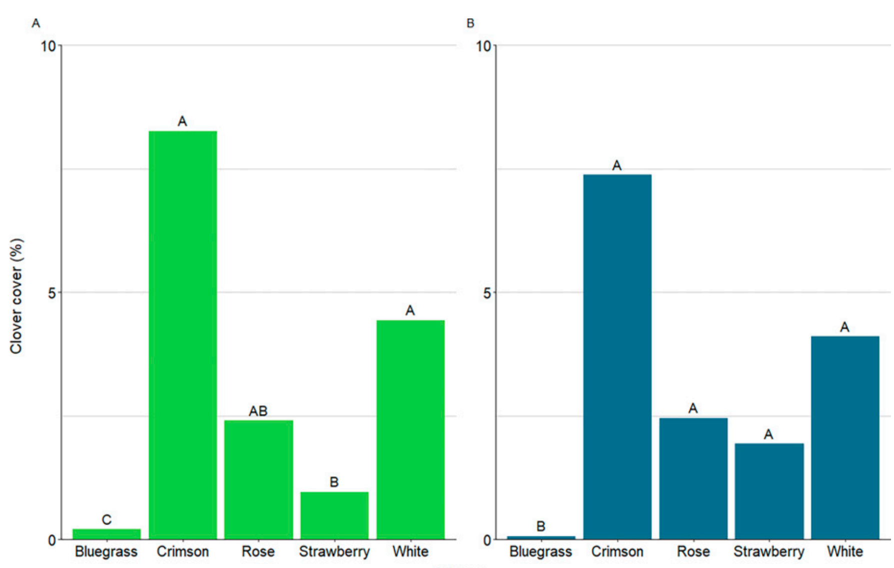

Fig. 4. Mean percentage of clover cover for (**A**) unfertilized and (**B**) fertilized (48.8 kg·ha^{-1} N) Kentucky bluegrass monocultures or dicultures of Kentucky bluegrass grown with crimson, rose, strawberry, or white clover in 2020. Bars within a fertilization treatment with different letters are significantly different ($P < 0.0001$).

Grass and weed and bare soil cover were not significantly different between 2020 treatments (Figs. 5 and 6), likely because of the poor clover establishment and high weed pressure across all plots. Because of delays related to COVID-19, there was a 10-d period between the time the study area was overcut to open the canopy and the time when the clover was seeded. The lack of grass cover reduced competition, and black medic was observed germinating and establishing before clover germination was observed. Ants (Formicidae) were observed moving clover seed after seeding, which may also have affected clover germination success negatively. Black medic was the dominant weed across all plots. Other weeds in the 2020 plots included bindweed, foxtail, dandelion, and prostrate knotweed. Crimson clover and white clover were also observed occasionally outside their respective treatment areas, indicating seed movement did occur between plots.

Stand quality. In 2019, significantly more unfertilized dicultures had acceptable quality compared with the unfertilized Kentucky bluegrass monocultures (Fig. 7). This indicates that for low-input lawns, clover dicultures can maintain better overall quality than Kentucky bluegrass monoculture lawns without fertilization. Strawberry and white clover dicultures did not differ significantly in the percent of plots of acceptable quality. However, strawberry clover dicultures maintained a consistently greater percentage of plots of acceptable quality compared with crimson and rose clovers (Fig. 7).

Lower quality values for crimson and rose clovers may be a function of color. Turf Analyzer evaluates the dark-green color index and assigns a greater value to darker green, healthy, high-chlorophyll turfgrass or turfgrass with a naturally darker genetic color. Because strawberry and white clovers are a darker green compared with the lime-green and gray-green to dark reddish purple of crimson and rose clovers, respectively, their values were likely naturally greater. Density and uniformity also may have played a role in quality ratings, as crimson clover has a more bunch-type growth habit compared with the other clovers in our study, which may have resulted in a nonuniform appearance. The high percentage of bare-soil and weed cover in Kentucky bluegrass plots also likely resulted in lower density and uniformity values, leading to lower overall quality ratings for Kentucky bluegrass plots.

Fertilized strawberry clover dicultures had a consistently and significantly greater percentage of plots of acceptable quality than fertilized Kentucky bluegrass monocultures, whereas fertilized crimson and rose clover dicultures often maintained significantly greater or similar percentage of acceptable quality than bluegrass monocultures (Fig. 7). Fertilized white clover dicultures maintained a similar percentage of plots of acceptable quality to Kentucky bluegrass monocultures (Fig. 7). Thus, regardless of fertilization, clover dicultures can maintain similar or greater quality than Kentucky bluegrass monocultures

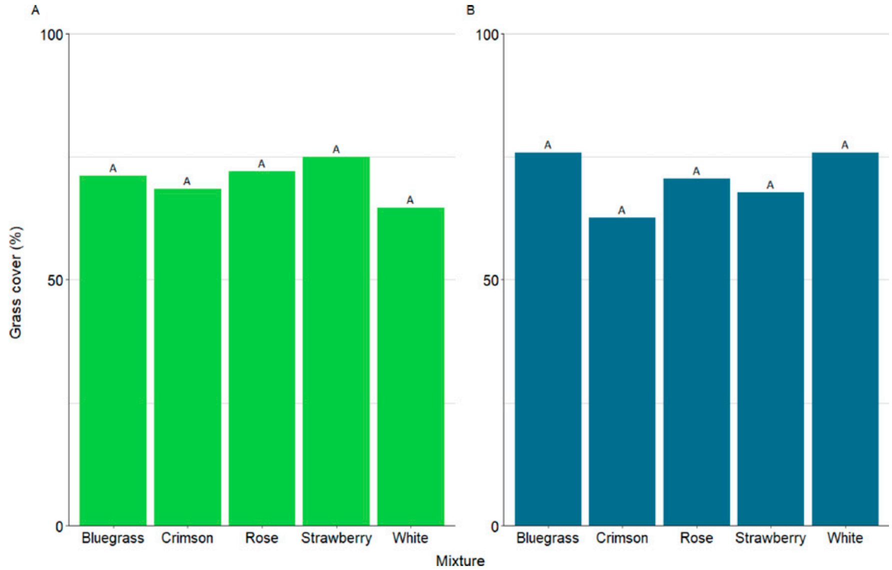

Fig. 5. Mean percentage of grass cover for (**A**) unfertilized and (**B**) fertilized (48.8 kg·ha^{-1} N) Kentucky bluegrass monocultures or dicultures of Kentucky bluegrass grown with crimson, rose, strawberry, or white clover in 2020. Bars within a fertilization treatment with different letters are significantly different ($P < 0.0001$).

and may be a suitable alternative to maintaining a dense, green, uniform lawn.

Shredding and browning of crimson clover foliage after mowing was observed. It is possible that mowing frequency may affect stand quality by shredding and browning leaves, and reducing green cover. Extending the period between mowing or increasing the mowing height may enhance clover cover and visual quality, but more research is needed on mowing frequency and mowing quality of clover dicultures, along with general clover–turfgrass diculture quality and persistence. Defoliation can also result in the loss of nodules and reduce the rate of legume nodule formation (Chu and Robertson 1974). In a managed turfgrass system, regular mowing, particularly when combined with supplemental N fertilization, may affect the ability of clover to fix N or persist in the mixture. For dicultures, a clover with a slow, prostrate growth may be more desirable to reduce mowing requirements and maintain stand height uniformity, rather than a clover such as crimson clover, which exhibited a more erect growth habit.

Potential barriers to adoption. There are several potential barriers to adoption of clover inclusion in lawns. One major barrier is the necessary limitation on herbicide use to control broadleaf weeds, as many broadleaf herbicides damage clovers. For example, late-summer applications of 2,4-D at 0.28 or 0.42 mL·m^{-2} resulted in a 15% to 50% reduction in microclover cover, although the microclover recovered by the following spring (Landschoot and Carroll 2016). 4-(2,4-dichlorophenoxy)butyric acid will not injure microclover (Landschoot and Carroll 2016) or white clover (McCurdy et al. 2016) severely, but it is not registered for residential use. In a study of herbicide tolerance in clover–turfgrass mixtures, pronamide, halosulfuron, bentazon, imazethapyr, imazamox, simazine, nicosulfuron, metribuzin, and 2,4-D did not reduce clover density significantly compared with nonherbicide-treated controls (McCurdy et al. 2016). MCPA is labeled for use in lawns and may cause slight discoloration or damage to microclover (Landschoot and Carroll 2016); however, MCPA resulted in 58% and 78% control of white and crimson clovers, respectively, when applied to mixed clover and bermudagrass rangeland stands (McCurdy et al. 2013a), and efficacy on other broadleaf weeds that may be targeted in dicultures is limited when used alone (Landschoot and Carroll 2016). Spot herbicide applications could still be used to target weeds while reducing potential exposure and damage to the clover.

Alternatively, nonchemical cultural practices may be used to improve cover and density, and to reduce weed pressure in dicultures. Hand-removal of weeds is an option for smaller diculture stands, but may not be practical for large lawns or turfgrass areas. Proper irrigation and fertilization can help maintain a dense stand and crowd out weeds; however, more research is needed on specific irrigation and fertilization recommendations for dicultures to help support the balance between turfgrass and clover health and density while reducing weed pressure. Because N fertilization may also reduce flowering of dicultures (Macke 2016), more research is also needed on the impact of flowering and associated pollinator support of dicultures.

In addition, the presence of bees and other pollinators could be problematic or undesirable in some settings (Duke et al. 2016; Ramer et al. 2019), especially urban lawns used by children and pets or adults with bee allergies. If this is an issue, the clover can be mown to remove flowers, although this may affect reseeding and long-term establishment efforts, particularly of annual species, which would need to be reseeded each year.

Another potential barrier is the "moral economy" of lawn care—the responsibility to uphold the ideal of a perfectly manicured lawn for the collective good of the community. The traditional dark-green, weed-free lawn aesthetic remains a highly valued trait across the United States (Feagan and Ripmeester 1999; Larson et al. 2016). The lighter green-to-red color of the crimson and rose clovers may not uphold this dark-green aesthetic value. In addition, in a society that spends USD450 million annually on lawn herbicides and plant growth regulators (Atwood and Paisley-Jones 2017), making the switch to alternative lawns that incorporate

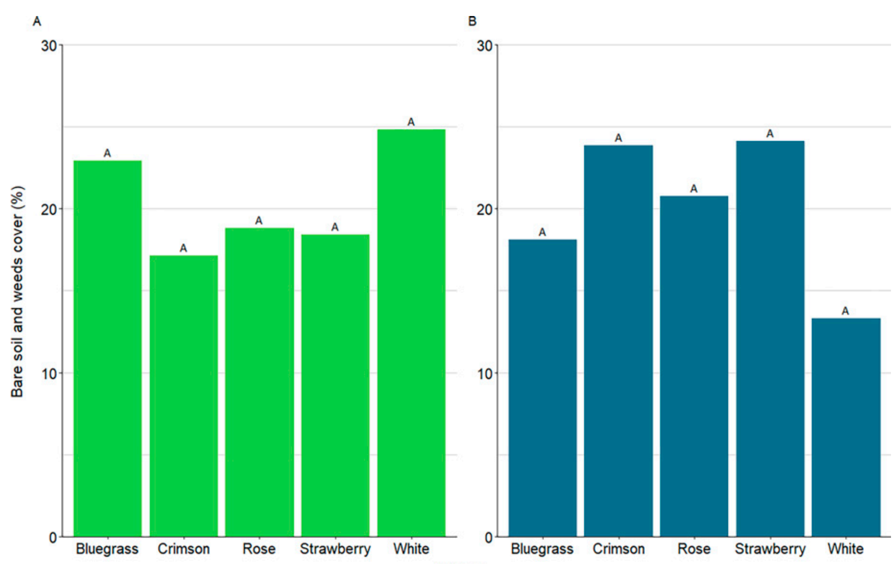

Fig. 6. Mean percentage of weed and bare-soil cover for (**A**) unfertilized and (**B**) fertilized (48.8 kg·ha^{-1} N) Kentucky bluegrass monocultures or dicultures of Kentucky bluegrass grown with crimson, rose, strawberry, or white clover in 2020. Bars within a fertilization treatment with different letters are significantly different ($P < 0.0001$).

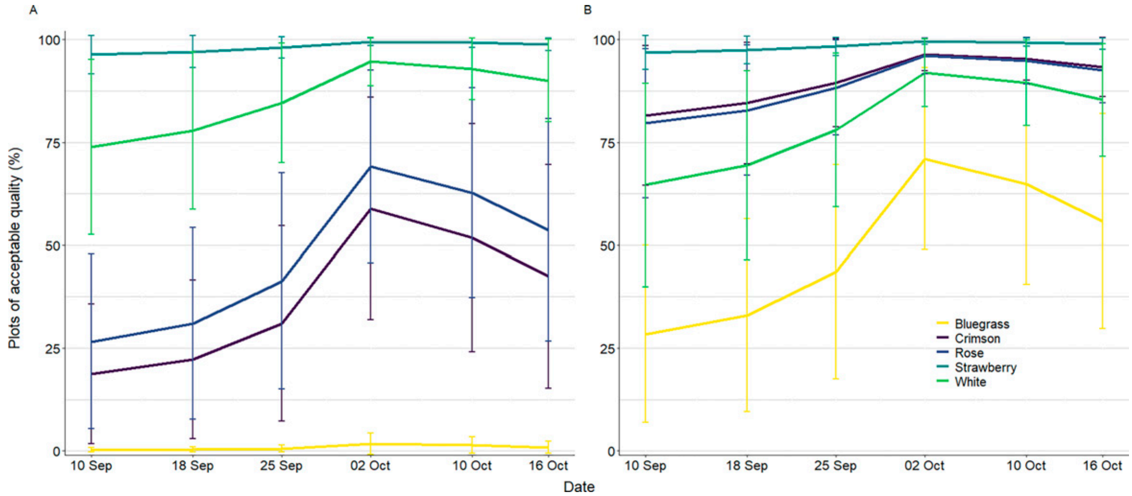

Fig. 7. Percentage of (**A**) unfertilized and (**B**) fertilized (48.8 kg·ha^{-1} N) plots with acceptable quality in 2019. Kentucky bluegrass was grown as a monoculture or as a diculture with crimson, rose, strawberry, or white clover. Error bars indicate standard error.

clover, which is commonly considered a lawn weed, may disrupt this standard and be a difficult practice for homeowners to adopt. There is often a negative association between a lawn manager (homeowner) failing to conform to this dark-green, weed-free cultural paradigm and poor personal character (Feagan and Ripmeester 1999; Robbins et al. 2001). This obligation may be enforced in subdivisions with set rules on accepted lawncare practices or quality parameters (such as homeowners' association guidelines) or by city ordinance (e.g., Hanchek 1994), which may prohibit clover inclusion in the home lawn and which may be used to force homeowners to tend to their lawns within set limits of acceptability. If neglected, citations, fines, and other penalties may follow (Feagan and Ripmeester 1999). Even when this obligation is not enforced directly, the potential guilt and the desire to adhere to social norms can overpower a lawn manager's guilt created by the application of various inputs, including chemicals and water (Harris et al. 2013). With the increase in municipal bylaws restricting nonessential and cosmetic pesticide use (Cole et al. 2011), however, the perception of the home lawn may need to shift. Purposeful incorporation of mixed stands may help either guide or respond to this shift.

Despite societal pressure to maintain pristine home lawns, a majority of park users surveyed supported the idea of flowering lawns in parks, and 96.5% of respondents like the way flowering lawns look (Ramer et al. 2019). The shift toward flowering lawns, whether the main goal is to reduce inputs or to support pollinators, could start with public spaces, such as parks, roadsides, and utility turfgrass, where public perception may be more lenient. This may then encourage homeowners to adopt the practice of incorporating flowers, including clovers, into their own lawns as they get more used to the idea of the mixed lawn. The cultural idea of a lawn as a high-input system can and should be challenged by individuals who push the boundaries of what is acceptable, and who aim to reduce inputs and broaden the ecology of the turfgrass lawn.

References Cited

Atwood D, Paisley-Jones C. 2017. Pesticides industry sales and usage: 2008–2012 Market estimates. US Environmental Protection Agency, Washington, DC, USA. https://www.epa.gov/pesticides/pesticides-industry-sales-and-usage-2008-2012-market-estimates. [accessed 12 Sep 2023].

Baltensperger AA, Gaussoin RE. 1985. Fresa strawberry clover, *Trifolium fragiferum* L., in reduced maintenance polystands and as a monostand ground cover. Proceedings of the Fifth International Turfgrass Research Conference, Avignon, France. 311–315.

Bigelow CA, Macke GA, Johnson K, Richmond DS. 2022. Cool-season lawn performance as influenced by 'microclover' inclusion and supplemental nitrogen. Int Turfgrass Res J. 2021:121–132. https://doi.org/10.1002/its2.19.

Boyle PE, Wisdom MM, Richardson MD. 2020. Testing flowering perennial plants in a bermudagrass (*Cynodon* spp.) lawn. HortScience. 55(10):1642–1646. https://doi.org/10.21273/HORTSCI15197-20.

Braun RC, Straw CM, Soldat DJ, Bekken MAH, Patton AJ, Lonsdorf EV, Horgan BP. 2023. Strategies for reducing inputs and emissions in turfgrass systems. Crop Forage Turfgrass Manag. 9(1):e20218. https://doi.org/10.1002/cft2.20218.

Chu ACP, Robertson AG. 1974. The effects of shading and defoliation on nodulation and nitrogen fixation by white clover. Plant Soil. 41:509–519. https://doi.org/10.1007/BF02185812.

Cole DC, Vanderlinden L, Leah J, Whate R, Mee C, Bienefeld M, Wanigaratne S, Campbell M. 2011. Municipal bylaw to reduce cosmetic/non-essential pesticide use on household lawns: A policy implementation evaluation. Environ Health. 10:74. https://doi.org/10.1186%2F1476-069X-10-74.

Cook T. 2005. Low maintenance turf? https://agsci.oregonstate.edu/beaverturf/low-maintenance-turf. [accessed 10 Oct 2023].

Duble RL. 1996. Turfgrasses: Their management and use in the southern zone (2nd ed). Texas A&M University Press, College Station, TX, USA.

Duke JM, Bruck J, Barton S, Murray M, Inamdar S, Tallamy DW. 2016. Public preference for ecosystem services on exurban landscapes: A case study from the Mid-Atlantic, USA. Heliyon. 2(7):e00127. https://doi.org/10.1016/j.heliyon.2016.e00127.

Elgersma A, Nassiri M, Schlepers H. 1998. Competition in perennial ryegrass-white clover mixtures under cutting: 1. Dry-matter yield, species composition and nitrogen fixation. Grass Forage Sci. 53:353–366. https://doi.org/10.1046/j.1365-2494.1998.00151.x.

Evers GW. 1995. Methods of rose clover establishment into bermudagrass sod. J Prod Agric. 8(3):366–368. https://doi.org/10.2134/jpa1995.0366.

Feagan RB, Ripmeester M. 1999. Contesting natural(ized) lawns: A geography of private green space in the Niagara region. Urban Geogr. 20(7):617–634. https://doi.org/10.2747/0272-3638.20.7.617.

Gibeault VA, Leonard M. 1987. Strawberry clover and common bermudagrass combination turf for low maintenance and energy conservation. Calif Turfgrass Cult. 27(1):4–5.

Hanchek AM. 1994. In the eye of the beholder: The case of the Minnetonka lawn ordinance. HortTechnology. 4(3):304–310. https://doi.org/10.21273/HORTTECH.4.3.304.

Harris EM, Martin DG, Polsky C, Denhardt L, Nehring A. 2013. Beyond "lawn people": The role of emotions in suburban yard management practices. Prof Geogr. 65:345–361. https://doi.org/10.1080/00330124.2012.681586.

Hejduk S, Kvasnovský M. 2014. Comparison of white clover cultivars in low input turfs. Eur J Turfgrass Sci. 45:23–24.

Hofmann RW, Lin W, Stilwell SA, Lucas RJ. 2007. Comparison of drought resistance in strawberry clover and white clover. Proc N Z Grassl Assoc. 69:219–222. https://doi.org/10.33584/jnzg.2007.69.2658.

Høgh-Jensen H, Schjoerring JK. 1997. Interactions between white clover and ryegrass under contrasting nitrogen availability: N_2 fixation, N fertilizer recovery, N transfer and water use efficiency. Plant Soil. 197:187–199. https://doi.org/10.1023/A:1004289512040.

Ignatieva M, Haase D, Dushkova D, Haase A. 2020. Lawns in cities: From a globalised urban green space phenomenon to sustainable nature-based solutions. Land (Basel). 9(73):1–27. https://doi.org/10.3390/land9030073.

Karcher DE, Richardson MD. 2013. Digital image analysis in turfgrass research, p 1133–1150. In: Stier JC, Horgan BP, Bonos SA (eds). Agronomy monograph 56 turfgrass: Biology, use, and management. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America Inc., Madison, WI, USA.

Knight WE. 1985. Crimson clover, p 491–502. In: Taylor NL (ed). Clover science and technology. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America Inc., Madison, WI, USA.

Kopp K, Johnson P. 2011. Basic turfgrass care. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1850&context=extension_curall. [accessed 5 May 2024].

Landschoot P, Carroll M. 2016. Tolerance of microclover to postemergence and preemergence herbicides. Crop. Forage Turfgrass Manag. 2(1):1–3. https://doi.org/10.2134/cftm2015.0226.

Lane IG, Wolfin J, Watkins E, Spivak M. 2019. Testing the establishment of eight forbs in mowed lawns of hard fescue (Festuca brevipila) for use in pollinator conservation. HortScience. 54:2150–2155. https://doi.org/10.21273/HORTSCI14336-19.

Larson JL, Kesheimer AJ, Potter DA. 2014. Pollinator assemblages on dandelions and white clover in urban and suburban lawns. J Insect Conserv. 18(5):863–873. https://doi.org/10.1007/s10841-014-9694-9.

Larson KL, Nelson KC, Samples SR, Hall SJ, Bettez N, Cavender-Bares J, Groffman PM, Grove M, Heffernan JB, Hobbie SE, Learned J, Morse JL, Neill C, Ogden LA, O'Neil-Dunne J, Pataki DE, Polsky C, Chowdhury RR, Steele M, Trammell TLE. 2016. Ecosystem services in managing residential landscapes: Priorities, value dimensions, and cross-regional patterns. Urban Ecosyst. 19:95–113. https://doi.org/10.1007/s11252-015-0477-1.

Love RM. 1985. Rose clover, p 536–546. In: Taylor NL (ed). Clover science and technology. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America Inc., Madison, WI, USA.

Macke GA. 2016. Evaluation of a cool-season grass-white clover mixture for low-nitrogen input lawns (MS Thesis). Purdue University, West Lafayette, IN, USA.

McCurdy JD, McElroy JS, Flessner ML. 2013a. Differential response of four *Trifolium* species to common broadleaf herbicides: Implications for mixed grass-legume swards. Weed Technol. 27(1):123–128. https://doi.org/10.1614/WT-D-12-00093.1.

McCurdy JD, McElroy JS, Flessner ML, Hoyle JA, Parker ET. 2016. Tolerance of three clovers (*Trifolium* spp.) to common herbicides. Weed Technol. 30(2):478–485. https://doi.org/10.1614/WT-D-15-00062.1.

McCurdy JD, McElroy JS, Guertal EA. 2013b. White clover (*Trifolium repens*) establishment within dormant bermudagrass turf: Cultural considerations, establishment timing, seeding rate, and cool-season companion grass species. HortScience. 48(12):1556–1561. https://doi.org/10.21273/HORTSCI.48.12.1556.

McCurdy JD, McElroy JS, Guertal EA, Wood CW. 2014. White clover inclusion within a bermudagrass lawn: Effects of supplemental nitrogen on botanical composition and nitrogen cycling. Crop Sci. 54(4):1796–1803. https://doi.org/10.2135/cropsci2013.10.0696.

Natural Resources Conservation Service. 2009. Plant guide for crimson clover (*Trifolium incarnatum* L.). US Department of Agriculture, Natural Resources Conservation Service, Plant Materials Program. https://plants.sc.egov.usda.gov/DocumentLibrary/factsheet/pdf/fs_trin3.pdf. [accessed 12 Sep 2023].

Oregon State University Forage Information System. 2018. Species. https://forages.oregonstate.edu/matchclover/species. [accessed 12 Sep 2023].

Potter DA, Redmond CT, McNamara TD, Munshaw GC. 2021. Dwarf white clover supports pollinators, augments nitrogen in clover–turfgrass lawns, and suppresses root-feeding grubs in monoculture but not in mixed swards. Sustainability. 13:11801. https://doi.org/10.3390/su132111801.

Ramer H, Nelson KC, Spivak M, Watkins E, Wolfin J, Pulscher M. 2019. Exploring park visitor perceptions of "flowering bee lawns" in neighborhood parks in Minneapolis, MN, US. Landsc Urban Plan. 189:117–128. https://doi.org/10.1016/j.landurbplan.2019.04.015.

Robbins P, Polderman A, Birkenholtz T. 2001. Lawns and toxins: An ecology of the city. Cities. 18(6):369–380. https://doi.org/10.1016/S0264-2751(01)00029-4.

Skogley CR, Sawyer CD. 1992. Field research, p 589–614. In: Waddington DV, Carrow RN, Shearman RC (eds). Turfgrass agronomy monograph 32. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America Inc., Madison, WI, USA.

Sparks B, Munshaw G, Williams D, Barrett M, Beasley J, Woosley P. 2015. Preplant cultivation techniques and planting date effects on white clover establishment into an existing cool-season turfgrass sward. HortScience. 50(4): 615–620. https://doi.org/10.21273/HORTSCI.50.4.615.

St. John L, Ogle DG. 2008. Plant guide for white clover (*Trifolium repens* L.). US Department of Agriculture, Natural Resources Conservation Service. Idaho Plant Materials Center, Aberdeen, ID, USA. https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_trre3.pdf. [accessed 12 Sep 2023].

St. John L, Ogle DG, Tilley D. 2010. Plant guide for strawberry clover (*Trifolium fragiferum*). US Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, Corvalis, OR, USA. https://plants.usda.gov/DocumentLibrary/plantguide/docold/pg_trfr2.docx. [accessed 12 Sep 2023].

Townsend CE. 1985. Miscellaneous perennial clovers, p 563–578. In: Taylor NL (ed). Clover science and technology. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America Inc., Madison, WI, USA.

Van Keuren RW, Hoveland CS. 1985. Clover management and utilization, p 325–354. In: Taylor NL (ed). Clover science and technology. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America Inc., Madison, WI, USA.

Volesky JD, Mowrey DP, Smith GR. 1996. Performance of rose clover and hairy vetch interseeded into Old World bluestem. J Range Manag. 49:448–451. https://doi.org/10.2307/4002928.

Wheeler MM, Neill C, Groffman PM, Avolio M, Bettez N, Cavender-Bares J, Chowdhury RR, Darling L, Grove JM, Hall SJ, Heffernan JB, Hobbie SE, Larson KL, Morse JL, Nelson KC, Ogden LA, O'Neil-Dunne J, Pataki DE, Polsky C, Steele M, Trammell TLE. 2017. Continental-scale homogenization of residential lawn plant communities. Landsc Urban Plan. 165:54–63. https://doi.org/10.1016/j.landurbplan.2017.05.004.

Young-Mathews A. 2013. Plant guide for crimson clover (*Trifolium incarnatum*). US Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, Corvallis, OR, USA. https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_trin3.pdf. [accessed 12 Sep 2023].