Clover–Turfgrass Lawns, Nitrogen Fertilization, and Pollinator Conservation

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The runoff or leaching of nitrogen fertilizers from monoculture turfgrass lawns contributes to water pollution, and such lawns are susceptible to insect pests and provide few resources for pollinators. One approach to creating more sustainable lawns is to incorporate white clover (*Trifolium repens* L.), a nitrogen-fixing legume, into grass seed mixtures or existing turfgrass swards. Besides augmenting nitrogen in lawns, clover also supports bees and other pollinators.

Keywords: Trifolium repens ; Schedonorus arundinaceus ; pollinators ; Popillia japonica ; low-input lawns

1. Introduction

Lawns are a pervasive feature of urban and suburban landscapes worldwide [1][2]. Traditionally defined as “ground covered with closely mowed vegetation, usually grasses” [3], lawns dominate residential lots, institutional and commercial landscapes, parks, cemeteries, playgrounds, street verges, and medians, occupying an estimated 39–54% of the total area devoted to urban development in the continental United States [4]. Traditional turfgrass lawns provide aesthetic, recreational, and human psychological and physical health benefits while providing ecosystem services; e.g., reducing soil erosion and surface runoff, dissipating heat through evaporative cooling, and reducing noise and glare compared with impervious surfaces [2][5][6][7]. Turfgrass lawns also sequester atmospheric carbon [4][8][9][10], although those benefits may be more than offset by the amounts of fossil fuels, water, nitrogen, and pesticides used in lawn maintenance [4][10][11][12]. Thus, there is growing interest in alternative lawns needing fewer resource inputs and providing greater ecosystem services than traditional all-turfgrass lawns [1][2].

Nitrogen (N) fertilization is a common cultural practice for establishing and maintaining turfgrass lawns. Nitrogen enhances sward density, color, and vigor, and is the nutrient required in the highest amount by the grass plant [13]. However, lawn fertilizers that are applied off-target to impervious surfaces, such as driveways and sidewalks, or to dormant, dying, or dead turfgrass can be moved by irrigation or rainfall into bodies of water, contributing to non-point source pollution [14][15]. In addition, N applied in soluble forms (e.g., urea) can result in nitrates leaching into groundwater [16].

One way to reduce the need for N inputs is to incorporate white clover (*Trifolium repens* L.), a nitrogen-fixing legume, into grass seed mixtures or existing turfgrass swards. Productive mixtures of white clover and cool-season turfgrasses can often fix between 100 and 200 kg N ha^{-1} $year^{-1}$ with positive effects on turfgrass growth, color, and visual appeal [17][18]. The typical recommended N fertilization rates for moderately maintained cool-season turfgrass lawns range from 98–195 kg N ha^{-1} $year^{-1}$. Consequently, if white clover can supply just a portion of a lawn’s annual N needs, the resulting reductions in fertilizer use could be substantial [19].

Trifolium repens, a perennial forb of Eurasian origin [20], was introduced into North America during the early colonial period, and has also been exported to other temperate regions of the world [20]. It grows naturally in pastures and along roadsides where climatic and soil conditions are suitable, and is intentionally seeded in mixed grass/clover pastures. “Dutch” white clover (DWC) is the vernacular term for a ubiquitous landrace found in many landscapes. Like all *T. repens*, it grows and spreads via stolons that root at the nodes [20]. A common component of lawn seed mixes before World War II, DWC fell out of favor with the introduction and marketing of broadleaf weed lawn herbicides in the 1950s. Furthermore, DWC tends to form taller, dark green clover-only patches that reduce lawn uniformity, and its flowers attract bees [21][22][23], which some people, e.g., persons with sting allergies or families with small children, may consider to be a hazard.

Microclover® (DLF-Pickseed, Tangent, OR) is a dwarf variety of white clover (*T. repens* var. “Pipolina”) selected for its small leaf size and low growth habit to allow it to tolerate low mowing heights and to blend in with cool-season turfgrasses without clumping or outcompeting the grass [19][24][25][26]. Used at a low rate in grass seed mixtures, or seeded into an

existing turf stand, it supplies N to the grass and helps to prevent the establishment of weeds by increasing the canopy density [26]. Microclover® was bred to have fewer and smaller flowers than DWC, although it will flower more if mowed less frequently (L. Brilman, DLF-Pickseed, pers. comm.). *Trifolium repens* var. “Barbian”, marketed as Turf Clover (Barenbrug USA, Tangent, OR), is another dwarf clover variety developed to blend more easily with turfgrasses than DWC.

In the United States where there are normative social pressures to maintain lawns as low-mowed turfgrass monocultures [27][28], spontaneous flowering forbs such as clover, the common dandelion (*Taraxacum officinale* F.H. Wigg.), and violets (*Viola* spp.) are traditionally viewed as undesirable weeds to be eliminated. Indeed, the US home and garden sector spent USD 450 million on lawn herbicides and plant growth regulators in 2012 [29]. That mindset seems to be changing, however, as the public becomes more aware of the threats to honey bee health [30], as well as steep declines in the populations of wild bees and other pollinators [31][32][33][34]. A reduction in floral resources (nectar and pollen) due to urbanization and other land-use changes is thought to be a major factor contributing to wild pollinator decline, especially in North America and Europe [32][35][36]. Urban ecologists are increasingly encouraging the conversion of traditional monoculture turfgrass lawns to more diverse habitats (e.g., [2][37]). Millions of citizens engage in ecological gardening and landscaping to support pollinators [38][39], and there is a growing public acceptance of flowering lawns in community parks [40] and residential yards [41][42][43].

Trifolium repens produces copious amounts of pollen and nectar [36][44][45], and is highly attractive to wild bees and honey bees that forage in urban landscapes [21][22][23][46][47][48][49]. It is the most important nectar source in Britain [45], providing the highest portion of total nectar production by flowering plants in parks, cemeteries, and road verges, and more than half of the total nectar resources in lawns and other mowed amenity grasslands [36]. Due to its prolonged bloom period, *T. repens* can help to sustain pollinators during seasonal gaps in floral resource availability from other plants [46][49][50]. Clover lawns can serve as stepping stones for the movement of bees and other pollinators between gardens, natural-area remnants, and other urban green spaces [21][37][51][52][53]. Such connectedness of floral resources is thought to be important for supporting species richness and an abundance of urban bees [54][55][56][57]. Clearly, if most homeowners, schools, and parks dedicated just a portion of their lawns to clover, the benefits to urban bee conservation could be substantial. Besides planting it, encouraging spontaneous *T. repens* by reducing lawn herbicide use and mowing less frequently are other ways to augment the food supply for urban bees [21][58][59].

White clover monostands are intolerant of heavy foot traffic, and are thus unsuitable for competitive sports fields or busy playgrounds [20][60]. Mixed clover–turfgrass swards, however, are relatively more resilient to foot traffic [18][20], and therefore suitable for use in home lawns, park lawns, medians, and other low-to-medium traffic sites [24][61]. White clover is relatively intolerant of shade, high heat and drought, and winter cold, which can cause canopy dieback and leave bare areas that can become muddy and require reseeding [20][61]. Attaining and maintaining a consistent percentage of clover to grass is difficult [20] as clover often disappears from mixed swards over several years [62], however it can be reseeded back in. It is also intolerant of many broadleaf herbicides, which can limit options for weed control, although some herbicides provide selective control of some broadleaf weeds in mixed clover–turfgrass swards [63][64]. Breeding for dwarf clover genotypes that are more resistant to environmental stress may improve their persistence [24].

2. Dwarf White Clover Supports Pollinators, Augments Nitrogen in Clover–Turfgrass Lawns, and Suppresses Root-Feeding Grubs in Monoculture but Not in Mixed Swards

Reconciliation ecology, “the science of inventing, establishing, and maintaining new habitats to conserve species diversity in places where people live, work, and play” [65], seeks ways to modify urban landscapes to support native biota without compromising societal utilization. Even in communities where there are normative social pressures to maintain residential and commercial front lawns as turfgrass monocultures, other sites, including backyards, institutional grounds, community parks, cemeteries, and street verges and medians, offer opportunities to integrate low-growing flowers into mowed turfgrass without compromising aesthetics or use for informal games and sports, picnicking, dog-walking, or other recreational activities [2][40]. However, movement to clover lawns to support pollinators and reduce the need for nitrogen fertilizer and other lawn chemicals will require changes in the aesthetic expectations of homeowners, turfgrass managers, and the general public. Using dwarf varieties of *T. repens* that blend into the turfgrass sward may encourage a greater acceptance of clover lawns [19].

This study indicates that dwarf white clover supplies nitrogen to tall fescue to a similar degree as Dutch white clover. The elevation in foliar N for grass in association with clover ranged from 17–23%, depending on the clover type, which is comparable to increases that were obtained in tall fescue turf by applying 150–200 kg N/ha per year [66]. All three clover types bloomed profusely in the monocultures and produced similar numbers of flowers when incorporated into existing

turf-type tall fescue. Despite their generally smaller bloom size, both dwarf clover varieties were visited by similar types of bees as those foraging on DWC. The monocultures of all the clover types had very few white grubs compared with the plots of tall fescue alone, although a similar reduction in grub numbers did not occur in the clover–tall fescue dicultures. Except for somewhat higher populations of leafhoppers and froghoppers, which caused no obvious aesthetic damage, the invertebrate communities in all three clover–tall fescue dicultures were similar to those found in plots of tall fescue alone.

Nitrogen is a limiting element in the diet of most plant-feeding insects [67], with a higher nitrogen content commonly associated with increased performance [66][67]. Black cutworms grew more quickly on all clover types than on tall fescue, likely due to the clovers' higher foliar nitrogen and lower fiber content. While it is also possible that by augmenting the foliar nitrogen in the associated turfgrasses, the clover in the mixed stands could confer associational susceptibility [68], causing the grass to become nutritionally more suitable for graminivorous pests, the same caveat applies when grasses are fertilized with other nitrogen sources [66]. In this study, however, none of the field plots sustained noticeable damage from cutworms or other grass-feeding caterpillars (e.g., sod webworms (Crambidae) or armyworms (*Spodoptera*, *Mythimna spp.*)) that feed on the same suite of cool-season lawn grasses [69].

Herein collected 17 different bee species foraging on *T. repens* in our monoculture clover plots, compared with 31 and 56 species of bees found in previous surveys of bees visiting spontaneous white clover in urban and suburban park lawns and other lawn sites in Kentucky and Minnesota, respectively [21][43]. The lower species richness in this study doubtless reflects the fact that the bees were collected from replicated plots at a single site, a turfgrass research facility; whereas in the previous surveys, bees foraging on *T. repens* were sampled across 16–18 established lawn sites surrounded by relatively more diverse vegetation. In the Minnesota study, the number of bee species collected on clover at a given site ranged from 5–17 in a given year, suggesting that dwarf clovers, too, would recruit additional bee species if planted more widely. Notably, in each of the three aforementioned studies, ≥90% of the non-*Apis* bee species that were sampled from *T. repens* are native to the United States, underscoring that this non-native flowering legume hosts a range of polylectic wild urban bees. Although *A. mellifera* and *Bombus spp.* (especially *B. impatiens*) were numerically dominant in all three studies, we found *Bombus spp.*, all native, were even more abundant than *A. mellifera* in late summer. White clover blooms and provides floral resources for much of the growing season, a characteristic that is particularly valuable to pollinators such as *A. mellifera* and *Bombus spp.* that have season-long foraging activity [70]. A caveat to our study is that we did not measure the quantity of nectar and pollen provided by the dwarf clovers versus DWC. It is possible that the dwarf clovers' value to bees could be somewhat reduced if foraging workers must visit more blooms to obtain equivalent floral rewards.

Low-maintenance turfgrass lawns typically harbor numerous species of predatory invertebrates, mostly generalist feeders, that collectively help to regulate populations of herbivorous invertebrates, including pests [71][72]. The epigeal and arboreal predators we found inhabiting the dwarf and DWC monocultures and clover–tall fescue dicultures, including spiders (mostly Linyphiidae, Erigonidae, and Lycosidae), ants (mostly *Lasius* and *Solenopsis spp.*), ground beetles, rove beetles, lady beetles, and predatory Hemiptera, were typical of those found in turf and pasture grass in the eastern United States [73][74][75]. Our samples also contained small parasitic wasps, which were not identified because their trophic relationships in cool-season turfgrasses are largely unknown [69][71]. Herbivores and earthworms in the clover plots also were similar to those inhabiting turf-type tall fescue lawns in Kentucky [66][75]. Overall, we saw no indication that incorporating dwarf clovers into tall fescue would significantly change the invertebrate community of lawns.

Herein found very low numbers of *P. japonica* grubs in all clover monocultures compared with the tall fescue and mixed clover–tall fescue plots. Larval *P. japonica* feed on the roots of a wide range of plants, including all cool-season turfgrasses [76], but according to Fleming [77], they "do not thrive" in plantings of *T. repens* or other *Trifolium* species. Studies with another generalist root herbivore, *Melolontha melolontha* (L.) (Scarabaeidae), suggested that *T. repens* resistance to its grubs is more likely due to a high root lignin content resulting in reduced feeding, as opposed to chemical repellence [78]. Many *T. repens* genotypes contain foliar cyanogenic glucosides [79], which deter the feeding and oviposition of some non-adapted insect herbivores [80]. However, adult *P. japonica* feed on the foliage of many cyanogenic plants, including *T. repens* [77], therefore it seems unlikely that those chemicals account for *T. repens* resistance to the grubs. White clover roots also contain flavonoids [81], but whether they play any role in resistance to root-feeding scarab grubs is unknown.

Importantly, *P. japonica* grub populations were not reduced in any of our clover–tall fescue dicultures compared with tall fescue alone, suggesting that incorporating dwarf or DWC into turf-type tall fescue will not provide associational resistance [68] to the grass itself, at least not at the clover density we attained by over-seeding it into existing tall fescue (e.g., **Figure 1**C,D). It is possible that by starting with a seed mix containing a relatively high proportion of clover, or by reseeding additional clover into a mixed sward, one could establish mixed clover–tall fescue lawns with enhanced

resistance to *P. japonica*. Further research on how clover monocultures and various ratios of clover to turfgrass affect white grub species other than *P. japonica*, and other lawn insect pests, is warranted. Regardless of the agronomic challenges of obtaining and maintaining a consistent, optimal percentage of clover to grass to match the aesthetic, recreational, and other use requirements for particular sites, the benefits of dwarf clover for supporting pollinators and reducing the need for inorganic or synthetic organic fertilizers justify their more widespread use in low-input lawns.

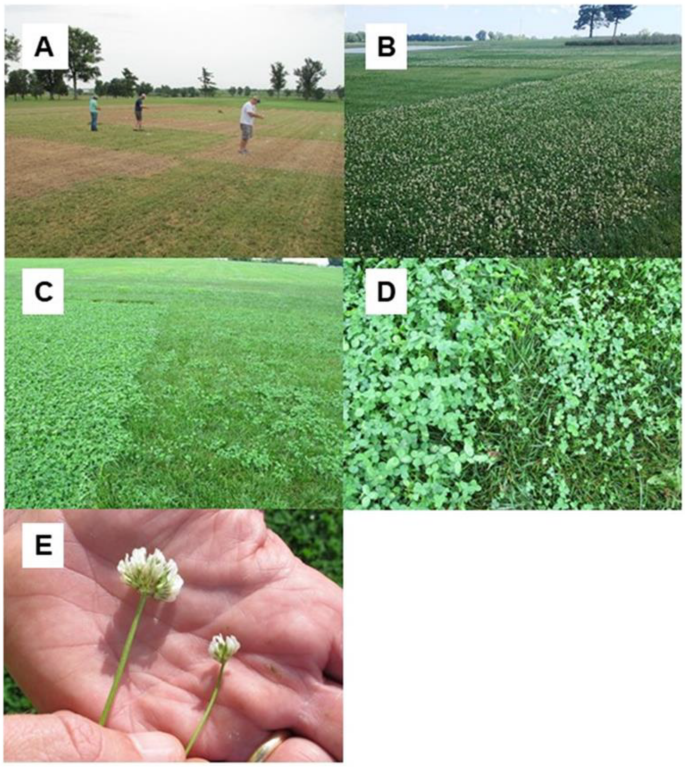

Figure 1. (**A**) Seeding the field plots, June 2015. (**B**) Cover monoculture plot in bloom, June 2016. (**C**) Interface of monoculture clover and clover–tall fescue diculture plot. (**D**,**E**) Differences in "Dutch" white clover and Microclover leaf and flower sizes.

References

1. Ignatieva, M.; Hedblom, M. An alternative green carpet. Science 2018, 362, 148–149.
2. Ignatieva, M.; Haase, D.; Dushkovam, D.; Haase, A. Lawns in cities: From a globalized urban green space phenomeno n to sustainable nature-based solutions. Land 2020, 9, 73.
3. Beard, J.B. Turf Management for Golf Courses, 2nd ed.; Wiley: New York, NY, USA, 2001.
4. Milesi, C.; Running, S.W.; Elvidge, C.D.; Dietx, J.B.; Tuttle, B.T.; Nemani, R.R. Mapping and modelling the biogeochemi cal cycling of turfgrass in the United States. Environ. Manag. 2005, 36, 426–438.
5. Beard, J.B.; Green, R.L. The roles of turfgrasses in environmental protection and their benefits to humans. J. Environ. Qual. 1994, 23, 452–460.
6. Daniels, B.; Zaunbrecher, B.S.; Paas, B.; Ottermanns, R.; Ziefle, M.; Roß-Nickoll, M. Assessment of urban green space structures and their quality from a multidimensional perspective. Sci. Total Environ. 2018, 615, 1364–1378.
7. Monteiro, J.A. Ecosystem services from turfgrass landscapes. Urban For. Urban Green. 2017, 26, 151–157.
8. Bandaranayake, W.; Qian, Y.; Parton, W.; Ojima, D.; Follett, R. Estimation of soil organic carbon changes in turfgrass s ystems using the CENTURY model. Agron. J. 2003, 95, 558–563.
9. Zirkle, G.; Lal, R.; Augustin, B. Modeling carbon sequestration in home lawns. HortScience 2011, 46, 808–814.
10. Selhost, A.; Lal, R. Net carbon sequestration potential and emissions in home lawn turfgrasses of the United States. En viron. Manag. 2013, 51, 198–208.
11. Blanco-Montero, C.A.; Bennett, T.B.; Neville, P.; Crawford, C.S.; Milne, B.T.; Ward, C.R. Potential environmental and ec onomic impacts of turfgrass in Albuquerque, New Mexico (USA). Landscape Ecol. 1995, 10, 121–128.
12. Grube, A.; Donaldson, D.; Kiely, T.; Wu, L. Pesticides Industry Sales and Usage: 2006 and 2007 Market Estimates; U. S. Environmental Protection Agency: Washington, DC, USA, 2011.

13. Turner, T.R.; Hummel, N.W., Jr. Nutritional requirements and fertilization. In Turfgrass; Waddington, D.W., Carrow, R.N., Shearman, R.C., Eds.; Agronomy Monographs Series; American Society of Agronomy; Crop Science Society of Americ a; Soil Science Society of America: Madison, WI, USA, 2002; Volume 32, pp. 385–439.
14. Law, N.; Band, L.; Grove, M. Nitrogen input from residential lawn care practices in suburban watersheds in Baltimore C ounty, MD. J. Environ. Plan. Manag. 2004, 47, 737–755.
15. US EPA. Polluted Runoff: Nonpoint Source: Urban Areas. 2017. Available online: https://www.epa.gov/nps/nonpoint-so urce-urban-areas (accessed on 24 October 2021).
16. Robertson, G.; Groffman, P. Nitrogen transformations. Soil Microbiol. Ecol. Biochem. 2007, 3, 341–364.
17. Jørgensen, F.V.; Jensen, E.S.; Schjoerring, J.K. Dinitrogen fixation in white clover grown in pure stand and mixture with ryegrass estimated by the immobilized 15N isotope dilution method. Plant Soil 1999, 208, 293–305.
18. Sincik, M.; Acikgoz, E. Effects of white clover inclusion on turf characteristics, nitrogen fixation, and nitrogen transfer fro m white clover to grass species in turf mixtures. Comm. Soil Sci. Plant Anal. 2007, 38, 1861–1871.
19. Sparks, B.; Munshaw, G.; Williams, D.; Barrett, M.; Beasley, J.; Woosley, P. Preplant cultivation techniques and planting date effects on white clover establishment into an existing cool-season turfgrass sward. HortScience 2015, 50, 615–62 0.
20. Frame, J.; Newbould, P. Agronomy of white clover. Adv. Agron. 1986, 40, 1–88.
21. Larson, J.L.; Kesheimer, A.J.; Potter, D.A. Pollinator assemblages on dandelions and white clover in urban and suburb an lawns. J. Insect Conserv. 2014, 18, 863–873.
22. MacIvor, J.S.; Cabral, J.M.; Packer, L. Pollen specialization by solitary bees in an urban landscape. Urban Ecosyst. 201 4, 17, 139–147.
23. Lerman, S.B.; Milam, J. Bee fauna and floral abundance within lawn-dominated suburban yards in Springfield, MA. An n. Entomol. Soc. Am. 2016, 109, 713–723.
24. Van der Heijden, S.A.G.; Roulund, N. Genetic gain in agronomic value of forage crops and turf: A review. In Sustainable Use of Genetic Diversity in Forage and Turf Breeding; Huyghe, S., Ed.; Springer: Dordrecht, The Netherlands, 2010; p p. 247–260.
25. Hejduk, S.; Kvasnovský, M. Comparison of white clover cultivars in low input turfs. Eur. J. Turfgrass Sci. 2014, 45, 23–2 4.
26. Brilman, L. Reducing nitrogen loss by using microclover in turf and reclamation blends. Land and Water 2016, 60, 37–4 1.
27. Blaine, T.W.; Clayton, S.; Robbins, P.; Grewal, P.S. Homeowner attitudes and practices towards residential landscape management in Ohio, USA. Environ. Manag. 2012, 50, 257–271.
28. Held, D.W.; Potter, D.A. Prospects for managing turfgrass pests with reduced chemical inputs. Annnu. Rev. Entomol. 2 012, 57, 329–354.
29. Atwood, D.; Paisley-Jones, C. Pesticides Industry Sales and Usage: 2008–2012 Market Estimates; U.S. Environmental Protection Agency: Washington, DC, USA, 2017.
30. Seitz, N.; Traynor, K.S.; Steinhauer, N.; Rennich, K.; Wilson, M.E.; Ellis, J.D.; Rose, R.; Tarpy, D.R.; Sagili, R.R.; Caron, D.M.; et al. A national survey of managed honey bee 2014–2015 annual colony losses in the USA. J. Apicult. Res. 201 5, 54, 292–304.
31. Potts, S.G.; Biesmeijer, J.C.; Kremen, C.; Neumann, P.; Schweiger, O.; Kunin, W.E. Global pollinator declines: Trends, i mpacts and drivers. Trends Ecol. Evol. 2010, 25, 345–353.
32. Goulson, D.; Nicholls, E.; Botias, C.; Rotheray, E.L. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 2015, 347, 1255957.
33. Cameron, S.A.; Lozier, J.D.; Strange, J.P.; Koch, J.B.; Cordes, N.; Solter, L.F.; Griswold, T.L. Patterns of widespread de cline in North American bumble bees. Proc. Nat. Acad. Sci. USA 2011, 108, 662–667.
34. Wagner, D.L.; Grames, E.M.; Forister, M.L.; Berenbaum, M.R.; Stopak, D. Insect decline in the Anthropocene: Death by a thousand cuts. Proc. Nat. Acad. Sci. USA 2021, 118, e2023989118.
35. Roulson, T.H.; Goodell, K. The role of resources and risks in regulating wild bee populations. Annu. Rev. Entomol. 201 1, 56, 293–312.
36. Tew, N.E.; Memmott, J.; Vaughan, I.P.; Bird, S.; Stone, G.N.; Potts, S.G.; Baldock, C.R. Quantifying nectar production b y flowering plants in urban and rural landscapes. J. Ecol. 2021, 109, 1747–1757.

37. Kawahara, A.K.; Reeves, L.E.; Barber, J.R.; Black, S.H. Opinion: Eight simple actions that individuals can take to save i nsects from global declines. Proc. Nat. Acad. Sci. USA 2021, 118, e2002547117.

38. National Pollinator Garden Network. Million Pollinator Garden Challenge. Available online: http://millionpollinatorgarden s.org (accessed on 24 October 2021).

39. Baldock, K.C.R. Opportunities and threats for pollinator conservation in global towns and cities. Curr. Opin. Insect Sci. 2020, 38, 63–71.

40. Ramer, H.; Nelson, K.C.; Spivak, M.; Watkins, E.; Wolfin, J.; Pulscher, M. Exploring park visitor perceptions of 'flowerin g bee lawns' in neighborhood parks in Minneapolis, MN, US. Landsc. Urban Plan. 2019, 189, 117–128.

41. Lane, I.G.; Wolfin, J.; Watkins, E.; Spivak, M. Testing the establishment of eight forbs in mowed lawns of hard fescue (F estuca brevipila) for use in pollinator conservation. HortScience 2019, 54, 2150–2155.

42. Del Toro, I.; Ribbons, R.R. No Mow May lawns have higher pollinator richness and abundances: An engaged communit y provides floral resources for pollinators. Peer J. 2020, 8, e10021.

43. Wolfin, J.; Watkinsm, E.; Lan, E.; Portman, Z.; Spivak, M. Floral enhancement of turfgrass lawns benefits wild bees and hone bees (Apis mellifera). Urban Ecosyst 2021, in press.

44. Roulston, T.H.; Cane, J.H. Pollen nutritional content and digestibility for animals. Plant Syst. Evol. 2000, 222, 187–209.

45. Baude, M.; Kunin, W.E.; Boatman, N.D.; Conyers, S.; Davies, N.; Gillepie, M.A.K.; Morton, R.D.; Smart, S.M.; Memmot t, J. Historical nectar assessment reveals the fall and rise of floral resources in Britain. Nature 2016, 530, 85–88.

46. Sponsler, D.B.; Shump, D.; Richardson, R.T.; Grozinger, C. Characterizing the floral resources of a North American met ropolis using a honey bee foraging assay. Ecosphere 2020, 11, e03102.

47. Verboven, H.A.F.; Aertsen, W.; Brys, R.; Hermy, M. Pollination and seed set of an obligatory outcrossing plant in an urb an–peri-urban gradient. Pers. Plant Ecol. Evol. Syst. 2014, 16, 121–131.

48. Kanduth, L.; Chartier, M.; Schönenberger, J.; Dellinger, A.S. Red and white clover provide food resources for honeybee s and wild bees in urban environments. Nordic J. Bot. 2021, 39, e03005.

49. Vaudo, A.D.; Tooker, J.F.; Grozinger, C.M.; Patch, H.M. Bee nutrition and floral resource restoration. Curr. Opin. Insect Sci. 2015, 10, 133–141.

50. Timberlake, T.P.; Vaughan, I.P.; Memmott, J. Phenology of farmland floral resources reveals seasonal gaps in nectar av ailability for bumblebees. J. Appl Ecol. 2019, 56, 1585–1596.

51. Hennig, E.I.; Ghazoul, J. Plant–pollinator interactions within the urban environment. Persp. Plant Ecol. Evol. Syst. 201 1, 13, 137–150.

52. Dover, J.; Settele, J. The influences of landscape structure on butterfly distribution and movement: A review. J. Insect C onserv. 2009, 13, 3–27.

53. Dearborn, D.C.; Kark, S. Motivations for conserving urban biodiversity. Conserv. Biol. 2010, 24, 432–440.

54. Banaszak-Cibicka, W.; Ratyńska, H.; Dylewski, Ł. Features of urban green space favourable for large and diverse bee populations (Hymenoptera: Apoidea: Apiformes). Urban For. Urban Green. 2016, 20, 448–452.

55. Beninde, J.; Veith, M.; Hochkirch, A. Biodiversity in cities needs space: A meta-analysis of factors determining intra-urb an biodiversity variation. Ecol. Lett. 2015, 18, 581–592.

56. Harrison, T.; Winfree, R. Urban drivers of plant-pollinator interactions. Func. Ecolo. 2015, 29, 879–888.

57. Turo, K.J.; Spring, M.R.; Silvakoff, F.S.; Delgado de la flor, Y.A.; Gardiner, M.M. Conservation in post-industrial cities: H ow does vacant land, management and landscape configuration influence urban bees. J. Appl. Ecol. 2021, 58, 58–69.

58. Bewrtoncini, A.P.; Machon, N.; Pavoine, S.; Muratet, A. Local gardening practices shape urban lawn floristic communiti es. Landsc. Urban Plan 2012, 105, 53–61.

59. Lerman, S.B.; Contosta, A.R.; Milam, J.; Bang, C. To mow or to mow less: Lawn mowing frequency affects abundance and diversity in suburban lawns. Biol. Conserv. 2018, 221, 160–174.

60. Brosnan, J.; Dickson, K.; Sorochan, J.; Thoms, A.; Stier, J. Large crabgrass, white clover, and hybrid bermudagrass ath letic field playing quality in response to simulated traffic. Crop Sci. 2014, 54, 1838–1843.

61. Turner, T.; Carroll, M. Microclover-Tall Fescue Lawns in the Mid-Atlantic region. University of Maryland Turfgrass Techni cal Update TT121. July 2015. Available online: http://www.mdturfcouncil.org/resources/Documents/TT%20Bulletins/TT-121%20Microclover%20_%20Tall%20Fescue%20Lawns%20in%20the%20Mid-Atlantic.pdf (accessed on 24 October 2 021).

62. NTEP 2019. National Turfgrass Evaluation Program. 2015 National Cool-Season (Low Input) Test. 2019. Available online: https://ntep.org/data/cs15l/cs15l_20-8/cs15lmo119t.txt (accessed on 24 October 2021).
63. McCurdy, J.D.; McElroy, J.S.; Guertal, E.A. White clover (Trifolium repens) establishment within dormant bermudagrass turf: Cultural considerations, establishment timing, seeding rate, and cool-season companion grass species. HortScience 2013, 48, 1556–1561.
64. Landschoot, P.; Carroll, M. Tolerance of microclover to postemergence and preemergence herbicides. Crop Forag. Turfgrass Manag. 2016, 2, 226.
65. Rosenzweig, M.L. Reconciliation ecology and the future of species diversity. Oryx 2003, 37, 194–205.
66. Davidson, A.W.; Potter, D.A. Response of plant-feeding, predatory, and soil-inhabiting invertebrates to Acremonium endophyte and nitrogen fertilization in tall fescue turf. J. Econ. Entomol. 1995, 88, 367–379.
67. Scriber, J.M.; Slansky, F., Jr. The nutritional ecology of immature insects. Annu. Rev. Entomol. 1981, 26, 183–211.
68. Barbosa, P.; Hines, J.; Kaplan, I.; Martinson, H.; Szczepaniec, A.; Szendrei, Z. Associational resistance and associational susceptibility: Having right or wrong neighbors. Annu. Rev. Ecol. Syst. 2009, 40, 1–20.
69. Vittum, P.J. Turfgrass Insects of the United States and Canada, 3rd ed.; Cornell University Press: Ithaca, NY, USA, 2020.
70. Pleasants, M. Bumblebee response to variation in nectar availability. Ecology 1981, 62, 1648–1661.
71. Bixby-Brosi, A.; Potter, D.A. Beneficial and innocuous invertebrates in turf. In Handbook of Turfgrass Insect Pests, 2nd ed.; Brandenburg, R., Freeman, C., Eds.; Entomological Society of America: Landham, MD, USA, 2012; pp. 87–93.
72. Cockfield, S.D.; Potter, D.A. Predatory insects and spiders from suburban lawns in Lexington, Kentucky. Great Lakes Entomol. 1984, 17, 179–184.
73. Dobbs, E.K.; Potter, D.A. Conservation biological control and pest performance in lawn turf: Does mowing height matter? Environ. Manag. 2014, 53, 648–659.
74. Keathley, C.P.; Potter, D.A. Arthropod abundance in tall fescue, Lolium arundinaceum, pastures containing novel ‘safe’ endophytes. J. Appl. Entomol. 2012, 136, 576–587.
75. Miller, D.M.; Redmond, C.T.; Flythe, M.D.; Potter, D.A. Evaluation of ‘Jackal’ AR601(Avanex) and Kentucky-31 endophytic tall fescues for suppressing types of invertebrates that contribute to bird strike hazard at airports. Crop Forag. Turfgrass Manag. 2017, 3, 1–11.
76. Potter, D.A.; Held, D.W. Biology and management of the Japanese beetle. Annu. Rev. Entomol. 2002, 47, 175–205.
77. Fleming, W.E. Biology of the Japanese Beetle; U.S. Department of Agricultur Technical Bulletins: Washington, DC, USA, 1972.
78. Hervé, M.R.; Erb, M. Distinct defense strategies allow different grassland species to cope with root herbivore attack. Oecologia 2019, 191, 127–139.
79. Gleadow, R.M.; Møller, B.L. Cyanogenic glycosides: Synthesis, physiology, and phenotypic plasticity. Annu. Rev. Plant Biol. 2014, 65, 155–185.
80. Ohashi, T.; Ohta, S.; Ômura, H. A cyanogenic glucoside of Trifolium repens deters oviposition by the common grass yellow Eurema mandarina. Physiol. Entomol. 2019, 44, 222–229.
81. Carlsen, S.; Understrup, A.; Fomsgaard, I.; Mortensen, A.; Ravnskov, S. Flavonoids in roots of white clover: Interaction of arbuscular mycorrhizal fungi and a pathogenic fungus. Plant Soil 2008, 302, 33–43.