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Review

Grasscycling: A Key Practice for Sustainable Turfgrass Management

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Abstract: For aesthetic considerations, grass clippings are removed from lawns during mowing. When turfgrass clippings are returned, this practice is called "mulching" or grasscycling. Thus, grasscycling has increasingly become a standard practice for low-input lawns managed under a simpler maintenance system, and grasscycling has many environmental benefits. Primarily, grasscycling facilitates an increase in soil nitrogen content and soil carbon sequestered by the turfgrass ecosystem. Several studies reported that grasscycling positively influences turfgrass colour and quality. When clippings are returned, turfgrass colour and quality can be maintained with a lower amount of fertilisation than turfgrass with clipping removal. Together with these positive effects, grasscycling practices can contribute to an increase of thatch in the turfgrass sward, while its influence on weed invasion is still questionable. This grasscycling practice can result in a maintenance cost-savings and represent a low-input approach to turfgrass management in terms of nutrients returned and utilised by the turfgrass, and with carbon (C) emissions mitigated and C sequestered. The unwelcome appearance linked to grass clipping residues and vegetation on the turfgrass canopy can be easily obviated by the use of machinery that delivers clippings forcefully toward the ground to incorporate them into the verdure or by using mowers that produce clippings small enough to be returned and quickly decomposed.

Keywords: turfgrass quality; footprint; mower design

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1. Introduction

Grass clippings from mowed lawns typically are removed, and this custom primarily is based on aesthetic considerations or pliability in the case of sports turfs [1]. When turfgrass clippings are cut into small particles and redistributed onto the newly mowed canopy, this practice is called "mulching". Rotary lawn mowers are designed to lift, cut, and discharge leaf tissue through side or rear orifices. Many lawn mowers offer a mulching-specific deck designed to cut leaf blades and subsequent clippings multiple times before discharging the "mulched" debris. However, there is a lack of information regarding clipping characteristics derived from different mowers [2] that makes it difficult to compare and evaluate a clipping size effect. For lawns, the term often used is "grasscycling", which is preferred over the term "mulching" to describe the practice of allowing turfgrass clippings to remain in situ when mowing. In the present review, the term grasscycling will be used regardless of mower practice used.

Returned clippings go through a degradation process affected by temperature and humidity [3], and by turfgrass species and cultivars [4], clipping dimensions, and type of mower [5]. Grasscycling increasingly has become a standard practice for maintaining low-input lawns. The reason can be attributed to a simpler maintenance system not requiring clipping collection, loading, hauling, and removal [6]. While this practice stems from financial and labour time choices, many environmental benefits are achieved as well. For example, grasscycling facilitates an increase of carbon (C) and nitrogen (N) content in the soil [7–12], reduces turfgrass N requirement [10,12–16], buffers soil temperature [17], preventing soil water loss by evaporation [18], and enhances turf quality by increasing colour and preventing weed invasion [15,19–27].

2. Implications on the Nutrient Cycle

When clippings are returned, they are gradually decomposed within the turf–soil system, thus releasing nutrients available to plants [15]. Few studies analysed mineral nutrients on clippings from turfgrass [28–30], while several studies investigated the N content of them. Liu and Hull [16] reported an average N concentration in turfgrass clippings of 42–45 mg g^{-1} of dry matter (DM) for Kentucky bluegrass (*Poa pratensis*), 41–44 mg g^{-1} DM for perennial ryegrass (*Lolium perenne*), and 33–39 mg g^{-1} DM for tall fescue (*Festuca arundinacea*), with a DM yield ranging from 3.68 t ha^{-1} for perennial ryegrass to 5.51 t ha^{-1} for tall fescue resulting in yearly N amount ranging from 111 to 260 kg N ha^{-1} (Table 1). Harivandi et al. [14], from a Kentucky bluegrass–perennial ryegrass mixture, found an amount of 156 kg N ha^{-1} in clippings (Table 1). Engelsjord et al. [13] obtained clippings containing 258 kg N ha^{-1} from Kentucky bluegrass and 241 kg N ha^{-1} from perennial ryegrass turfs (Table 1). In addition, Starr and DeRoo [12] found clippings with a N amount of 50 kg N ha^{-1}. All these studies suggest that turfgrass clippings returned can supply as much as 30–50% of annual N requirements (Table 1).

Table 1. Nitrogen (N) amount in clippings of turfgrass species as reported by several authors.

Species	**N Amount (kg ha^{-1})**	**Reference**
Kentucky bluegrass	260	Liu and Hull, 2016 [16]
	258	Engelsjord et al., 2004 [13]
Perennial ryegrass	260	Liu and Hull, 2016 [16]
	241	Engelsjord et al., 2004 [13]
Tall fescue	111	Liu and Hull, 2016 [16]
Mixture (Kentucky bluegrass and Red fescue)	50	Starr and DeRoo, 1981 [12]
Mixture (Kentucky bluegrass and Perennial ryegrass)	156	Harivandi et al., 2001 [14]

Although turfgrasses differ in clippings production and N content among species, cultivars, and fertilisation practices [4], clippings contribute substantially to the annual N budgets of turf–soil ecosystems, and this must be taken into consideration in turfgrass management strategies designed to increase N use efficiency and minimise N losses [21,31]. From this point of view, returning clippings after mowing can be a strategy to reduce the costs of N fertility by reducing the amount of N fertiliser applied and its potential environmental impact [26], even though the application of a minimum amount of mineral fertiliser is necessary to achieve optimum quality turfgrass [15].

The practice to return or remove clippings on the canopy also influences the N content of clippings. Cazzato et al. [32] examined clippings collected from tall fescue managed by clipping removal, and found the N concentration was lower (2.47% of DM) compared to tall fescue managed with returned clippings (2.89–2.96% of DM), suggesting that differences in clipping management may influence long-term efficiency of N utilisation. Knot et al. [15] and Qian et al. [10] applied the Century Model and calculated that returning clippings can reduce turfgrass' N requirement by 25% if it is from a 1–10 years old stand, by 33% if it is 11–25 years old, and >50% if it is older than 25 years.

Returning grass clippings resulted in an increase in total soil N concentration [8], and may increase soil C and N content if soil microbial activity is sufficient to mineralise N [7,9–12]. Turfgrass clipping decomposition has been reported to be fast, with 30% of turfgrass clipping's N mineralised within 7 days [33], independently of soil rootzone and microbial properties. Furthermore, 20% of C in the turfgrass clippings decomposed in the soil within seven days [34]. Returning grass clippings also has been found to increase soil C sequestered in turfgrass ecosystems, with an increase in total soil C concentration when clippings werereturned [8,10,33].

Shi et al. [35] noted that returned clippings increased N mineralisation in soil, although the response was short-lived (approximately 14 days), and net N mineralisation of clippings in the soil occurred rapidly, thus indicating the overall C:N ratio of easily decomposable compounds was low enough to provide inorganic N in excess of microbial N assimilation.

3. Mulch Effect of Turfgrass Clippings

The term "mulch" is defined as materials (i.e., straw, tree and shrub waste, leaves, bark, turfgrass clippings, etc.) that are applied over the soil surface to cover it [36]. Several studies documented the effect of different types of mulches on the soil: round gravel, wood chips, and turfgrass clippings. Overall, mulches can buffer soil temperature [17], prevent soil water loss from evaporation [18,37], suppress weed germination and growth [25], enhance soil biological activities [38], and improve chemical and physical properties of soil [39,40]. Ni et al. [41] demonstrated that grasscycling with a 5 cm layer of turfgrass clippings significantly increased soil moisture in the upper soil layer (0–5 cm depth), and significantly increased soil organic matter content and soil C:N ratio up to 10 cm in depth.

Mulch protects soil from extreme temperatures [42–45] that could damage fine roots, especially in the upper shallow or near-the-surface soil profile. Furthermore, leaving mulches such as turfgrass clippings on the soil results in a release of water vapour through evapotranspiration and reduces surface temperatures by evaporative cooling [46]. However, turfgrass clippings do not provide protection from temperature conditions comparable to inorganic or wood chip mulches [47]. Turfgrass clippings are less effective and soil beneath the viable turfgrass canopy dries quickly, therefore, it is less protected against high temperatures [36]. Considering that turfgrass clippings returned after mowing lawns do not form a thick surface debris layer, the term "mulching" may not be appropriate to describe the method of handling turfgrass clippings by leaving them on the lawn during mowing. Lastly, more research is necessary to further investigate the potential beneficial effects of mulching derived from turfgrass clippings returned over the turfgrass canopy.

4. Impacts on the Turfgrass Aesthetics and Health

Several studies reported that grasscycling positively influences turfgrass colour, while other studies report the influence of grasscycling on turfgrass quality. The increase in turfgrass colour (i.e., visual darker green canopy) due to grasscycling has been reported for lawn swards [15,21], Kentucky bluegrass and tall fescue mixed stands [19,22,27], and tall fescue [20]. Heckman et al. [21], however, suggested that reducing fertilisation by 50% and returning turfgrass clippings did not impact turfgrass colour. Regarding turfgrass quality, in bermudagrass (*Cynodon* sp.), Schiavon et al. [26] and Johnson et al. [23] observed that returned clippings increased visual quality, especially towards the end of the growing season. In Kentucky bluegrass, Murray and Juska [24] reported that visual quality was higher when clippings were returned. In a lawn sward, Knot et al. [15] observed no reduction in overall quality when clippings were returned. Several authors studied Kentucky bluegrass and tall fescue mixtures that excel in transition conditions [19,22,27] and observed that grasscycling increased turfgrass quality compared with clippings removed entirely, and the same was found in a tall fescue monostand [20]. Furthermore, Kopp and Guillard [48] reported the reduction of N fertiliser application by 50% with clippings returned did not reduce turfgrass quality. Similarly, Heckman et al. [21] noted that reducing N fertilisation by 50% from 195.2 to 97.6 kg N ha^{-1} $year^{-1}$ while leaving clippings on the ground also did not decrease turfgrass quality.

The effect of grasscycling on weed management is still debated [49], because it may be considered to have a negative effect due to spreading of weed seed [21], or a positive effect since clippings returned may contribute allelochemical compounds into the soil [1]. Moreover, Knot [6] indicated that returning clippings over a grass–legume sward had a statistically significant effect on the long-term botanical composition of favouring grasses over the legumes. However, clippings removal led to a 60% reduction of viable annual bluegrass (*Poa annua*) seeds in a creeping bentgrass dominated sward [50]. In agreement with this study, Heckman et al. [21] reported a reduction of weeds when clippings are returned to the turfgrass, compared to clippings collected, and Pavel et al. [15] demonstrated a significant control on the expansion of legumes. Since clippings are part of the leaf blade, they can contain allelochemical compounds that could result in herbicidal activity [51]. Wu et al. [52] conducted studies on allelopathic compounds isolated from clippings of perennial ryegrass, Kentucky bluegrass, and particularly red fescue (*Festuca rubra*), that inhibited germination and seedling growth of prostrate pigweed (*Amaranthus blitoides*) [51]. However, the role of turfgrass clippings on allelopathic-based inhibitory effects on weeds is still questionable, as allelopathic compounds interact with soil physical and chemical parameters, climate, and other biotic factors with effects that are often unpredictable [52].

Thatch formation should be considered when turfgrass clippings are released over the mowed canopy. A limited amount of thatch can be desirable as it buffers soil temperature extremes, reduces water loss from soil, reduces weed invasion, and increases wear tolerance [24,53]. When thatch thickness exceeds 20 mm, however, risk of damage to turfgrass increases and therefore thatch mitigation cultural practices become necessary [53,54]. The return of clippings has been associated with the development of a thick thatch layer (about 20 mm), which starts to become evident two years after sowing [32]. On the contrary, other studies found that thatch was not influenced by clippings [20,49]. More research is needed to assess this issue, and it seems that turfgrass species composition, mowing height and frequency, type of mowing machine used, fertiliser source and annual applied rate, irrigation practices, the soil root zone environment, and climate conditions can influence thatch accumulation.

Finally, other aspects should be deeply investigated on the effects of grasscycling on amenity and sports turfgrass, such as the effects on the root system. The presence of organic material constantly on top of the soil and thereby influencing shallow soil moisture and nutrient content, may affect root development in the deeper root zone profile. Despite limited information, two studies have been reported that returned clippings had no or a negative effect on root density for bermudagrass [26] or tall fescue [55].

5. Footprint Effect

Grasscycling has increasingly become a standard method used in maintaining low-input lawns. The reason can be attributed to cost-savings, as this maintenance program does not require loading and hauling of the mown material [6]. This practice also leads to a reduction in plastic use for trash bags (where used) and a reduction in C emissions by negating the use of those vehicles needed to transport the turf debris. Another point worthy of note, sending clippings in trash bags to the landfill leads to the production of methane, through anaerobic decomposition [56].

The first, and probably the most important, positive aspect of grasscycling is its potential effect on the N cycle and on other elements such as phosphorus and potassium on the turfgrass–soil ecosystem [28], as clippings returned could potentially reduce N fertilisation requirements of the turfgrasss [20,26]. Excessive N applications can have negative impacts on the environment, especially when quick-release N sources are used to fertilise turfgrass [57]. Since elevated levels of nitrate could be traced in groundwater in urban environments, the lowest minimum N requirements for turfgrasses and lawn swards need to be identified [58]. The return of clippings is a strategy for reducing fertiliser usage and costs [15,26] and for reducing C emissions due to costs of manufacturing, transporting, and commercialising synthetic fertiliser [59]. Wang et al. [34] have shown that a substantial amount of C fixation in turfgrass was allocated in producing above-ground biomass, therefore, clipping management can be a critical driver of C balance in turfgrass ecosystems. In addition, the practice of returning clippings reduces net greenhouse gasses by 12% [60]. Conversely, the greater availability of N from clippings leads to faster turfgrass growth [26,48], a taller sward height [61], and a substantial increase in turfgrass productivity [34] that may constrain homeowners to increase mowing frequency with the associated negative consequences on turfgrass maintenance costs and environmental impacts. However, this increase in turfgrass growth rate should be balanced by reducing N fertilisation inputs.

A potential increase in thatch because of grasscycling practices has both negative and positive effects. As mentioned previously, positive attributes of thatch include its ability to buffer soil temperature extremes and reduce water loss from soil [24], and this effect on soil moisture content is important considering drought conditions and low precipitation in some areas of the world [28]. However, when thatch thickness is too excessive to benefit turfgrass health, thatch reduction practices (i.e., verticutting, core cultivation, etc.) becomes necessary [54], which implies an increase in C emissions from the mechanised equipment. These C emissions can be offset by the consistent amount of C sequestration documented by several authors in lawn soil and root zones and turfgrasses that are maintained for several years [56]. Law et al. [8] reported after two years of mowing with turfgrass clippings returned, 3.3% more labile soil C and 3.3% more total soil C was measured compared to turfgrass with clippings collected.

Grasscycling directly influences the footprint of a turfgrass ecosystem for all of the aforementioned aspects and factors. However, the type of mower machine employed can have an influence on grasscycling, operating costs, and the environment. For example, battery-powered machinery has been reported to have superior energetic efficiency compared to the equivalent gasoline-powered machinery [62]. Mower machine and turfgrass management also affect the dimension of the clippings; this has an effect on the decomposition time of clippings, and the power requirement of the mower to perform and function [5]. Therefore, the larger the physical clipping's size, the longer time needed for decomposition.

6. Mower Design and Type

Mower design and operation have been based on reducing clipping size to enhance filtering into the turfgrass canopy away from the surface [2]. The decomposition speed turfgrass clippings is related to their physical dimensions. Small turfgrass clippings are more likely to filter down through the turfgrass canopy to the soil surface versus the larger turfgrass clippings. Many mowers offer a mulching option which closes discharge orifices resulting in completely enclosed decks, and others are mulching-specific decks designed for mulching operation only which they cut clippings multiple times before discharging onto the ground [2]. Nevertheless, the mower is not the only variable for having clippings with small dimensions or sizes, as the turfgrass species also can influence clipping sizes [2].

There are basically two types of lawn mower power supplies: electric and combustion engine. Currently, the petrol mowers are more powerful compared to electric mowers, and petrol mowers do not have potential problems or issues with the recharging time as with electric mowers. The electric mowers are more environmentally friendly, they do not need high maintenance, and have much less primary energy requirement. In the family of electric mowers there is a category inherent to the "autonomous mowers" who execute only the mulching practice. They are mowers powered by a battery that perform mowing without requiring a human operator [62], and always returning clippings onto the turfgrass canopy. Simply evaluating the effects on turfgrass quality, the biggest advantage of battery-powered mowers compared to traditional petrol mowers is that they cut smaller clippings because of the high mowing frequency, which then decompose faster [62].

7. Conclusions

For all intents and purposes, the grasscycling practice can be considered an essential strategy in modern turfgrass management. The reason can be attributed to cost-savings, low-input turfgrass management in terms of nutrients returned and utilised by the turfgrass, and mitigated C emission and raised C sequestration, especially if associated with the use of battery-powered mower machinery. Grasscycling has doubtful impacts on weed management, thatch accumulation, and root development. The lack of clear results is mainly due to species and climate condition effects. The unwelcome appearance linked to the sight of cutting residues and vegetation on the turfgrass can be easily obviated by the use of machinery that delivers the clippings forcefully towards the ground in order to incorporate them into the canopy, or by using battery-powered mowers which produce clippings small enough to be quickly decomposed.

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References

1. Hahn, D.; Sallenave, R.; Pornaro, C.; Leinauer, B. Managing cool-season turfgrass without herbicides: Optimizing maintenance practices to control weeds. *Crop Sci.* **2020**, *60*, 2204–2220. [CrossRef]
2. Miller, G.L.; Pinnix, G.D.; Bartley, P.C.; McCauley, R.K.; Jackson, B.E. Evaluation of Turfgrass Clippings from Mulching Versus Side Discharge Mower Operation. *Crop Forage Turfgrass Manag.* **2019**, *5*, 1–5. [CrossRef]
3. Rychnovská, M. *Structure and Functioning of Seminatural Meadows*; Elsevier: Amsterdam, The Netherlands, 2012.
4. Liu, H. Comparing cultivars of three cool-season turfgrasses for nitrate uptake kinetics and nitrogen recovery in the field. *Int. Turfgrass Soc. Res. J.* **1993**, *7*, 546–552.
5. Pirchio, M.; Fontanelli, M.; Frasconi, C.; Martelloni, L.; Raffaelli, M.; Peruzzi, A.; Gaetani, M.; Magni, S.; Caturegli, L.; Volterrani, M. Autonomous mower vs. rotary mower: Effects on turf quality and weed control in tall fescue lawn. *Agronomy* **2018**, *8*, 15. [CrossRef]
6. Knot, P. Clipping management and its effect on the composition and height of low-input turf. *Acta Univ. Agric. Et Silvic. Mendel. Brun.* **2013**, *61*, 192. [CrossRef]
7. Haley, J.; Wehner, D.; Fermanian, T.; Turgeon, A. Comparison of conventional and mulching mowers for Kentucky bluegrass maintenance. *Hortic. Sci.* **1985**, *20*, 105–107. [CrossRef]
8. Law, Q.D.; Trappe, J.M.; Jiang, Y.; Turco, R.F.; Patton, A.J. Turfgrass selection and grass clippings management influence soil carbon and nitrogen dynamics. *Agron. J.* **2017**, *109*, 1719–1725. [CrossRef]
9. MacDonald, A.J.; Powlson, D.S.; Poulton, P.R.; Jenkinson, D.S. Unused fertiliser nitrogen in arable soils—Its contribution to nitrate leaching. *J. Sci. Food Agric.* **1989**, *46*, 407–419. [CrossRef]
10. Qian, Y.; Bandaranayake, W.; Parton, W.; Mecham, B.; Harivandi, M.; Mosier, A. Long-term effects of clipping and nitrogen management in turfgrass on soil organic carbon and nitrogen dynamics: The CENTURY model simulation. *J. Environ. Qual.* **2003**, *32*, 1694–1700. [CrossRef]
11. Shepherd, M.; Stockdale, E.; Powlson, D.; Jarvis, S. The influence of organic nitrogen mineralization on the management of agricultural systems in the UK. *Soil Use Manag.* **1996**, *12*, 76–85. [CrossRef]
12. Starr, J.; DeRoo, H. The Fate of Nitrogen Fertilizer Applied to Turfgrass 1. *Crop Sci.* **1981**, *21*, 531–536. [CrossRef]
13. Engelsjord, M.; Branham, B.; Horgan, B. The fate of nitrogen-15 ammonium sulfate applied to Kentucky bluegrass and perennial ryegrass turfs. *Crop Sci.* **2004**, *44*, 1341–1347. [CrossRef]
14. Harivandi, M.; Hagan, W.; Elmore, C. Recycling mower effects on biomass, nitrogen recycling, weed invasion, turf quality, and thatch. *Int. Turfgrass Soc. Res. J* **2001**, *9*, 882–885.
15. Knot, P.; Hrabe, F.; Hejduk, S.; Skladanka, J.; Kvasnovsky, M.; Hodulikova, L.; Caslavova, I.; Horky, P. The impacts of different management practices on botanical composition, quality, colour and growth of urban lawns. *Urban For. Urban Green.* **2017**, *26*, 178–183. [CrossRef]
16. Liu, H.; Hull, R.J. Comparing cultivars of three cool-season turfgrasses for nitrogen recovery in clippings. *Hortic. Sci.* **2006**, *41*, 827–831. [CrossRef]
17. Greenly, K.M.; Rakow, D.A. The effect of wood mulch type and depth on weed and tree growth and certain soil parameters. *J. Arboric.* **1995**, *21*, 225. [CrossRef]
18. Gleason, M.; Iles, J. Mulch matters: The proper use of organic mulch offers numerous benefits for your woody landscape plants. *Am. Nurserym.* **1998**, *187*, 24–31.
19. Griggs, S.; Horst, G.; Rolph, C. *Influence of Mulching Mowers on Tall Fescue Lawns*; American Society of Agronomy: Madison, WI, USA, 1980; p. 117.

20. Grossi, N.; Volterrani, M.; Magni, S.; Miele, S. Caratteristiche qualitative del tappeto erboso di *Festuca arundinacea* Schreb. in funzione della gestione dei residui del taglio. In Proceedings of the 35th Conference of the Italian Society of Agronomy, Napoli, Italy, 16–18 September 2003; pp. 307–308.
21. Heckman, J.; Liu, H.; Hill, W.; DeMilia, M.; Anastasia, W. Kentucky bluegrass responses to mowing practice and nitrogen fertility management. *J. Sustain. Agric.* **2000**, *15*, 25–33. [CrossRef]
22. Horst, G.; Griggs, S.; Rolph, C. The Influence of Mulching Mowers on Established Lawns. *Prog. Rep.-Tex. Agric. Exp. Stn.* **1981**, *3831/3851*, 11–12.
23. Johnson, B.; Carrow, R.; Burns, R. Bermudagrass Turf Response to Mowing Practices and Fertilizer[1]. *Agron. J.* **1987**, *79*, 677–680. [CrossRef]
24. Murray, J.; Juska, F. Effect of Management Practices on Thatch Accumulation, Turf Quality, and Leaf Spot Damage in Common Kentucky Bluegrass[1]. *Agron. J.* **1977**, *69*, 365–369. [CrossRef]
25. Rathinasabapathi, B.; Ferguson, J.; Gal, M. Evaluation of allelopathic potential of wood chips for weed suppression in horticultural production systems. *Hortic. Sci.* **2005**, *40*, 711–713. [CrossRef]
26. Schiavon, M.; Pornaro, C.; Macolino, S. Clippings return decreases mineral nitrogen requirements for bermudagrass (*Cynodon* spp.) lawns in Mediterranean Europe. *Crop Sci.* **2021**, *61*, 2916–2925. [CrossRef]
27. Troll, J.; Hurto, K. *Comparative Turf Response from Conventional and Mulching Rotary Mowers on Kentucky Bluegrass Turf*; American Society of Agronomy: Madison, WI, USA, 1981; p. 128.
28. Grégoire, G.; Benjannet, R.; Desjardins, Y. Contribution of grass clippings to turfgrass fertilization and soil water content under four nitrogen levels. *Sci. Total Environ.* **2022**, *837*, 155765. [CrossRef] [PubMed]
29. Mehall, B.; Hull, R.; Skogley, C. Cultivar Variation in Kentucky Bluegrass: P and K Nutritional Factors[1]. *Agron. J.* **1983**, *75*, 767–772. [CrossRef]
30. Mehall, B.; Hull, R.; Skogley, C. Turf Quality of Kentucky Bluegrass Cultivars and Energy Relations[1]. *Agron. J.* **1984**, *76*, 47–50. [CrossRef]
31. Bigelow, C.A.; Waddill, D.W.; Chalmers, D.R. Turf-type tall fescue lawn turf response to added clippings. *Int. Turfgrass Soc. Res. J.* **2005**, *10*, 916–922.
32. Cazzato, E.; Anesse, V.; Corleto, A. Effects of clipping management on some aspects of tall fescue (*Festuca arundinacea* Schreb.) turf. In Proceedings of the 1st International Conference on Turfgrass Management and Science for Sports Fields, Athens, Greece, 2–7 June 2003; pp. 301–307.
33. Kauer, K.; Kõlli, R.; Viiralt, R.; Köster, T.; Noormets, M.; Laidna, T.; Keres, I.; Parol, A.; Varul, T.; Selge, A. Effect of cut plant residue management and fertilization on the dry-matter yield of swards and on carbon content of soil. *Commun. Soil Sci. Plant Anal.* **2013**, *44*, 205–218. [CrossRef]
34. Wang, R.; Mattox, C.M.; Phillips, C.L.; Kowalewski, A.R. Carbon Sequestration in Turfgrass–Soil Systems. *Plants* **2022**, *11*, 2478. [CrossRef]
35. Shi, W.; Muruganandam, S.; Bowman, D. Soil microbial biomass and nitrogen dynamics in a turfgrass chronosequence: A short-term response to turfgrass clipping addition. *Soil Biol. Biochem.* **2006**, *38*, 2032–2042. [CrossRef]
36. Chalker-Scott, L. Impact of mulches on landscape plants and the environment—A review. *J. Environ. Hortic.* **2007**, *25*, 239–249. [CrossRef]
37. Pirone, P.P.; Hartman, J.R.; Pirone, T.P.; Pirone, T.; Sall, M.A. *Pirone's Tree Maintenance*; Oxford University Press: Oxford, UK, 2000.
38. Blaise, D.; Velmourougane, K.; Santosh, S.; Manikandan, A. Intercrop mulch affects soil biology and microbial diversity in rainfed transgenic Bt cotton hybrids. *Sci. Total Environ.* **2021**, *794*, 148787. [CrossRef] [PubMed]
39. Cooper, A.J. *Root Temperatures and Plant Growth*; Research Reviews 4; Commonwealth Bureau of Horticulture and Plantation Crops: Tamil Nadu, India, 1973.
40. Hanada, T. *The Effect of Mulching and Row Covers on Vegetable Production*; ASPAC, Food & Fertilizer Technology: Taipei, Taiwan, 1991.
41. Ni, X.; Song, W.; Zhang, H.; Yang, X.; Wang, L. Effects of mulching on soil properties and growth of tea olive (Osmanthus fragrans). *PLoS ONE* **2016**, *11*, e0158228. [CrossRef] [PubMed]
42. Einert, A.; Guidry, R.; Huneycutt, H. Permanent mulches for landscape plantings of dwarf crape myrtles. *Am. Nurserym.* **1975**, *9*, 59–65.
43. Fraedrich, S.W.; Ham, D.L. Wood chip mulching around maples: Effect on tree growth and soil characteristics. *J. Arboric.* **1982**, *8*, 86–89. [CrossRef]
44. Kudinov, V. Sawdust instead of manure. *Sadovodstvo* **1972**, *12*, 38.
45. Long, C.E.; Thorne, B.L.; Breisch, N.L.; Douglass, L.W. Effect of organic and inorganic landscape mulches on subterranean termite (Isoptera: Rhinotermitidae) foraging activity. *Environ. Entom.* **2001**, *30*, 832–836. [CrossRef]
46. Montague, T.; Kjelgren, R. Energy balance of six common landscape surfaces and the influence of surface properties on gas exchange of four containerized tree species. *Sci. Hortic.-Amsterdam* **2004**, *100*, 229–249. [CrossRef]
47. Cregg, B.M.; Dix, M.E. Tree moisture stress and insect damage in urban areas in relation to heat island effects. *J. Arboric.* **2001**, *27*, 8–17.
48. Kopp, K.L.; Guillard, K. Clipping management and nitrogen fertilization of turfgrass: Growth, nitrogen utilization, and quality. *Crop Sci.* **2002**, *42*, 1225–1231. [CrossRef]
49. Brede, D. *Turfgrass Maintenance Reduction handbook: Sports, Lawns, and Golf*; John Wiley & Sons: Hoboken, NJ, USA, 2000.

50. Gaussoin, R.; Branham, B. Influence of cultural factors on species dominance in a mixed stand of annual bluegrass/creeping bentgrass. *Crop Sci.* **1989**, *29*, 480–484. [CrossRef]
51. Akbari, M.; Sajedi, N.; Gomarian, M.; Akbari, M. Allelopathic effects of cool-season turfgrass mixture clipping extract on four weed species and detection of the phenolic compounds. *Int. J. Hortic. Sci. Techol.* **2015**, *2*, 141–149.
52. Wu, L.; Harivandi, M.; Guo, X. Distribution of phenolic acids and allelopathic potential in cool-season and warm-season turfgrass species. *Calif. Turfgrass Cult* **2002**, *52*, 5–9.
53. Beard, J.B. *Turfgrass: Science and Culture*; Prentice-Hall, Inc.: Englewood Cliffs, NJ, USA, 1973.
54. Veronesi, F.; Falcinelli, M.; Panella, A. Cool season grasses for turf use in Italy. 2: Mowing, width of leaf blades and thatch layer [trials in umbria]. *Riv. Di Agron.* **1992**, *26*, 104–110.
55. Macolino, S.; Ziliotto, U. The impact of returned grass clippings on the root growth of Tall Fescue. *Int. Turfgrass Soc. Res. J.* **2005**, *10*, 976–981.
56. Milesi, C.; Running, S.W.; Elvidge, C.D.; Dietz, J.B.; Tuttle, B.T.; Nemani, R.R. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. *Environ. Manag.* **2005**, *36*, 426–438. [CrossRef]
57. Saha, S.K.; Trenholm, L.E.; Unruh, J.B. Effect of fertilizer source on nitrate leaching and St. Augustinegrass turfgrass quality. *Hortic. Sci.* **2007**, *42*, 1478–1481. [CrossRef]
58. Wu, L.; Green, R.; Klein, G.; Hartin, J.S.; Burger, D.W. Nitrogen source and rate influence on tall fescue quality and nitrate leaching in a southern California lawn. *Agron. J.* **2010**, *102*, 31–38. [CrossRef]
59. Schlesinger, W.H. Carbon sequestration in soils. *Science* **1999**, *284*, 2095. [CrossRef]
60. Gu, C.; Crane, J.; Hornberger, G.; Carrico, A. The effects of household management practices on the global warming potential of urban lawns. *J. Environ. Manag.* **2015**, *151*, 233–242. [CrossRef]
61. Knot, P.; Hrabě, F.; Vrzalova, J. Production of above-ground phytomass of turf grass species during their extensive exploitation. In Proceedings of the 16th Symposium of the European Grassland Federation, Gumpenstein, Austria, 29–31 August 2011; pp. 431–433.
62. Grossi, N.; Fontanelli, M.; Garramone, E.; Peruzzi, A.; Raffaelli, M.; Pirchio, M.; Martelloni, L.; Frasconi, C.; Caturegli, L.; Gaetani, M. Autonomous mower saves energy and improves quality of tall fescue lawn. *HortTechnology* **2016**, *26*, 825–830. [CrossRef]