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- Ausgabe 02/20: **„Drought, Irrigation and Water consumption“**
- Ausgabe 03/20: **„Disease and Pest Management + Biostimulants“**
- Ausgabe 04/20: **„Maintenance and Nutrition + Impact for the Environment“**

Inhalte Ausgabe 04/20

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Selected papers (Part 3/3) for the 7th ETS Conference 2020, cancelled due to Covid-19

The tolerance of *Poa pratensis* to low mowing heights

Hesselsøe, K.J., P. Heltoft, G. Thorvaldsson, A.M. Dahl Jensen, T. Espevig, W. Waalen, T.K. Petersen, T. Pettersen, J. Tangsveen, P. Sørensen, T. Gneist, B. Hannesson and T.S. Aamlid

Introduction

Poa pratensis (US: Kentucky bluegrass, UK: smooth-stalked meadow grass) is widely used for lawns, athletic fields and golf turf (except greens). The mowing tolerance range for *Poa pratensis* is 19-64 mm[1]. When mowing golf course fairways at 25 mm or lower, the P. pratensis will be infected by diseases or outcompeted by other grass species, e.g. *Poa annua*[2]. However, a research project comparing mixtures of *Lolium perenne* and *P. pratensis* on soccer fields in Norway from 2009 to 2011[3] showed that the proportion of *P. pratensis* in the turf was the same, whether it was mowed with a cylinder mower at 15 mm or a rotary mower at 30 mm. Research in the USA to find cultivars of *P. pratensis* that could be used on fairways in the transition zone also found, that certain cultivars mowed at 14 mm produced higher turf quality than blends of *L. perenne*[4]. Research from Denmark[5] claims that *P. pratensis* will be most tolerant to close mowing at high light intensity, cool temperatures and low humidity, and this is confirmed by our own observations on golf courses in Iceland and coastal areas of northern Norway, that *P. pratensis* can thrive even at less than 5 mm mowing height on greens. Thus, *P. pratensis* was included in the SCANGREEN 2015-18 test round[6], which aimed to find new species and varieties for putting greens at pesticide-free management in the Nordic countries. The objective for including of *P. pratensis* was to test its tolerance to low mowing and to evaluate, if *P. pratensis* could become an alternative species for putting greens commonly suffering from winter damage.

Material and Methods

SCANGREEN 2015-18 fields were established on four different USGA-spec. greens: at Reykjavik GC in Iceland, at NIBIO Apelsvoll and NIBIO Landvik in Norway and at Sydsjælland GC in Denmark. Reykjavik and Apelsvoll were considered to represent the northern, and Landvik and Sydsjælland, the southern climatic zone of the Nordic countries. At all four test sites there were three replicates of the experiment. The trials included 34 varieties representing the following turfgrass species: *Agrostis stolonifera, Agrostis capillaris, Agrostis canina, Festuca rubra, Lolium perenne, Poa trivialis, Poa annua* and *Poa pratensis*. The *P. pratensis* varieties tested were 'Limousine' and 'Becca' (the latter only at Landvik due to space limitations at the other sites). The seeding rate of *P. pratensis* was 15 g m^{-2}. The trials were evaluated from seeding in June 2015 until November 2018. The mowing height was 5 mm in *F. rubra, P. pratensis* and *L. perenne* and 3-4 mm in *Agrostis* sp., *P. trivialis* and *P. annua*. Fertilizers were applied at a seasonal rate of ≈10 g N m^{-2} in *F. rubra, A. canina* and *A. capillaris* and 15-16 g N m^{-2} in *L. perenne, A. stolonifera, P. pratensis* and *P. annua*. The trials were mowed three times per week, subjected to wear from greens-type wear machines and otherwise managed according to good greenkeeping practice. The plots were evaluated in the growing season for visual turf quality (scale 1-9, 9=the best), tiller density (scale 1-9, 9=the most dense), leaf fineness (scale 1-9, 9=finest), color (scale 1-9, 9=darkest), percent of plot area covered by undiseased turf of the seeded species, percent of plot area infected by disease, *P. annua* invasion (at Landvik only) and daily height increment (at Landvik only). Abiotic and biotic winter damage were assessed in spring. Due to limited plot area (1x1 m) they were not evaluated for playing quality. The experimental data were analyzed using the procedure PROC ANOVA.

Results and Discussion

In the first evaluation year 2016 *P. pratensis* produced higher turf quality scores than any other species in the Icelandic trial (data not shown) and scored highest (6.6) on average for all four sites (Table 1). At the northern trial site in Norway the winter survival was on the level with *A. stolonifera* and better than for the other species (data not shown). Half way through the project period (in 2017) the highest quality scores were still obtained with *P. pratensis* (Table 1). This was due to less winter damage and better disease resistance than any other species. The *P. pratensis* was dense, wear tolerant and had only few in-season diseases except for rust (*Puccina* spp.), mainly at the southern site in Denmark (data not shown). This is a well-known weakness of 'Limousine' and the trial at Landvik showed that 'Becca' was less susceptible. 'Becca' also had overall better spring performance and finer leaves, but lighter color than 'Limousine' (data not shown). In the last evaluation year 2018 the plots with *P. pratensis* were invaded by *P. annua* and other grass species, and this also declined turfgrass quality, so all in all the results showed, that *P. pratensis* cannot perform as a green grass, except at nor-

[1] TURGEON, A.J., 2002: Turfgrass management. Prentice Hall, Upper Saddle River, NJ, 397 p.

[2] CHRISTIANS, N., 2004: Fundamentals of turfgrass mangement. John Wiley & Sons, Hoboken, NJ. 162 p.

[3] AAMLID, T.S. and T. PETTERSEN, 2012: Lav klipping av engrapp og raigras på fotballbaner: Ikke mer tunrapp, men redusert rotutvikling. Gressforum 3: 8-9 (In Norwegian).

[4] KRAFT, R.W. and S.J. KEELEY, 2005: Evaluation of improved Poa pratensis cultivars for transition zone fairway use. Int. Turfgrass Soc. Res. J. 10:368-372.

[5] PETERSEN, M., 1980: Græsplæner – principper & funktioner. L. Dæhnfeldt, Denmark.

[6] AAMLID, T., P. HELTOFT, G. THORVALDSSON, A.M.D. JENSEN, T. ESPEVIG, K.J. HESSELSØE, W. WAALEN, T.K. PETERSEN, T. PETTERSEN, J. TANGSVEEN, P. SØRENSEN, T. GNEIST and B. HANNESSON, 2019: SCANGREEN 2015-18: Turfgrass species, varieties, seed mixtures and seed blends for Scandinavian putting greens. NIBIO REPORT 5(154). 100 p.

	Turfgrass quality (1-9)						Tiller density (1-9)	Leaf fineness (1-9)	Overall winter damage, %	Microdochium patch during winter, %	In-season diseases, %		
	Overall mean	Overall mean South zone	Overall mean North zone	2016	2017	2018					Microdochium	Red thread	Take-all
*	4	2	2	4	4	4	4	4	4	3	3	2	2
PP	5.8	5.6	6.0	6.6	6.2	5.1	5.7	4.2	15.4	0.5	0.1	0.1	0.0
AS	5.6	5.6	5.6	5.6	5.8	5.6	6.8	5.8	16.3	2.8	0.8	0.0	0.3
FRL	5.1	5.1	5.3	5.3	5.8	4.5	5.6	6.9	18.6	1.5	2.1	0.9	0.0
FRC	5.1	5.0	5.1	5.5	5.8	4.2	5.5	7.0	21.3	1.7	1.1	0.8	0.0
ACAP	4.5	4.9	4.8	4.7	4.8	4.1	6.5	6.0	29.9	4.3	1.6	0.0	1.2
LP	4.0	4.4	4.2	4.7	4.2	3.2	4.3	3.7	47.2	0.5	0.4	5.2	0.0
PT	3.8	3.5	4.1	5.1	3.4	2.3	4.6	5.2	43.5	4.7	0.8	0.4	0.1
PA	3.3	2.6	4.0	3.0	3.1	3.1	-	-	-	-	-	0.1	0.2
P%	<0.1	<0.1	3.7	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
LSD 5%	0.2	0.2	<0.1	0.2	0.3	0.4	0.1	0.1	4.0	2.1	0.2	0.5	0.4

*: Number of sites.

Tab. 1: Visual evaluation of PP=*Poa pratensis* ('Limousine') compared to *Poa annua* 'Two Put' and mean values across varieties for AS=*Agrostis stolonifera*, FRL=*Festuca rubra* spp. *litoralis*, FRC=*Festuca rubra* spp. *commutata*, ACAP=*Agrostis capillaris*, LP=*Lolium perenne*, PT=*Poa trivialis* at Landvik and Sydsjælland (Southern zone) and at Reykjavik and Apelsvoll (Northern zone).

thern sites with extreme winter conditions. However the results showed that *P. pratensis* tolerated mowing at 5 mm, which is much lower than we normally recommend, and it still got the best overall quality compared to the other species in the project. Though this project does not recommend *P. pratensis* as a green grass, it produced important knowledge as to the usability of new varieties of *P. pratensis* to be used on tees and fairways as mowing heights are lowering. However, the leaves were coarse and stiff, and this did not favour the playing quality for *P. pratensis* to be used as a green grass. Because the playing quality was not measured in the SCANGREEN 2015-18-project, this should be investigated further.

Authors:

Karin Juul Hesselsøe, Pia Heltoft, Tatsiana Espevig, Wendy Waalen, Trond Pettersen, Jan Tangsveen, Trygve S. Aamlid,
Norwegian Institute of Bioeconomy Research,

Gudni Thorvaldsson,
Agricultural University of Iceland,

Anne Mette Dahl Jensen,
University of Copenhagen,

Torben Kastrup Petersen,
Danish Golf Union,

Tania Gneist and Per Sørensen,
Sydsjælland Golf Course, Denmark,

Bjarni Hannesson,
Ness Golf Course, Iceland.

Optimal timing for preventative Pythium root rot management on golf course putting greens

Hampy, H.D. and J.P. Kerns

Introduction

Pythium root rot (PRR) is a detrimental disease of creeping bentgrass golf course putting greens in almost all regions of the world. Symptoms develop from June to September and include irregular necrotic patches of turf, canopy thinning, and root necrosis[1]. If not managed properly, this disease can quickly kill large areas on putting greens[2]. The disease is typically managed by spraying fungicides throughout the summer months. However, the timing of fungicide applications for preventative management is poorly understood due a lack of understanding about when the initial inoculum starts the process for infection. Therefore, the objective of this study is to evaluate the most efficacious time period to initiate a fungicide program in order to manage Pythium root rot symptoms on creeping bentgrass putting greens.

Material and Methods

This research was conducted at the Lake Wheeler Turfgrass Research and Education Center in Raleigh, NC from March 2019 to August 2019. The experimental area is a 'Dominant Plus' creeping bentgrass grown on a root zone meeting USGA putting green construction standards. The experimental area was maintained at a mowing height of 0.38 cm and received 2.27 kg per 92.9 m^2 of N annually. Potassium and phosphorus were applied if needed and irrigation was supplied to prevent drought stress prior during winter and spring. The putting green was core cultivated in March and August of 2019 and was only topdressed during aerification events. Pythium root rot was induced on the green by irrigating for 5 minutes at 6 pm, 12 am, and 6 am daily from May 2019 to June 2019. Once Pythium root rot developed, plots were irrigated daily for 5 minutes at 6 pm to maintain disease. Five treatments with four replicates each were arranged in a randomized complete block design. The area of each treatment block was 1.67 m^2. The fungicide applied was Segway® Fungicide SC with an active ingredient of Cyazofamid (400 g per liter) and manufactured by PBI-Gordon Corporation. Segway® Fungicide SC was dosed at 1.072 ml per treatment block mixture and sprayed at a rate of 13.3 ml per 92.9 m^2. Applications were made once every 28 days and immediately followed with 0.64 cm of post-application irrigation. Each treatment was initiated on a different month and all treatments received applications until July 2019. The starting dates for treatments 1-5 were March 14, April 10, May 8, June 4, and July 3, 2019, respectively. Treatments 1, 2, 3, 4 and 5 received 5, 4, 3, 2 and 1 applications, respectively. Disease severity was measured weekly by visually estimating the percentage of symptomatic turf in each block. Using SAS®

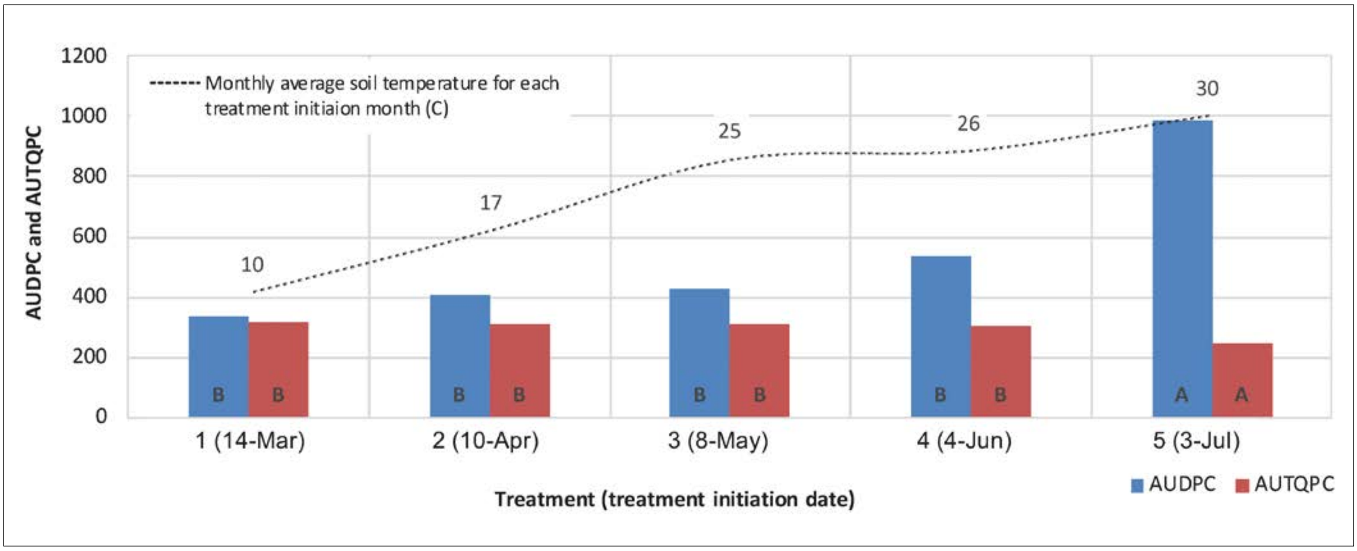

Fig. 1: Area under turf quality progress curve and area under disease progress curve influenced by total number of Segway® Fungicide SC applications. Rated on July 10, 2019. Means are separated with AUDPC and AUTQPC, respectively, according to Fischer's Protected Least Significant Difference test at *P*<0.05. Monthly average soil temperatures in degrees Celsius for months March through July in 2019.

[1] SCHROEDER, K.L., F.N. MARTIN, A.W. de COCK, C.F. LÉVESQUE, J. SPIES, P.A. OKUBARA and T.C. PAULITZ, 2013: Molecular Detection and Quantification of Pythium Species: Evolving Taxonomy, New Tools and Challenges. Plant Disease 2013 97:1, 4-20.

[2] ABAD, Z.G., H.D. SHEW and L.T. LUCAS, 1994: Characterization and pathogenicity of Pythium species isolated from turfgrass with symptoms of root and crown rot in North Carolina. Phytopathology 1994 Vol.84 No.9 pp.913-921 ref.75.

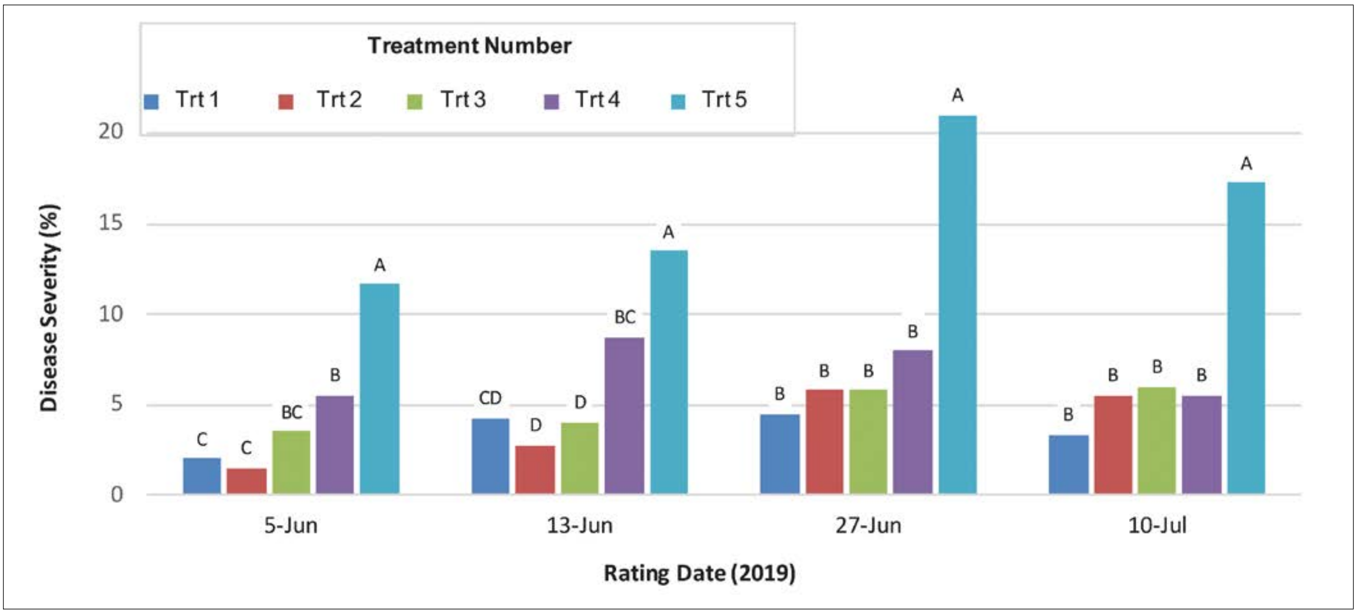

Fig. 2: Disease Severity Influenced by number of Segway® Fungicide SC applications. Applications were applied every 28 days and rated on Jun 5, Jun 13, Jun 27 and Jul 10, 2019. Means are separated within each treatment, according to Fischer's Protected Least Significant Difference test at *P*<0.05.

software, an analysis of variance was run and means were separated within each treatment and data was statistically analyzed using software Fisher's Protected Least Significant Difference test at *P*<0.05.

Results and Discussion

Monthly average soil temperatures for March through July in 2019 were 10, 17, 25, 26, and 30 °C, respectively (Figure 1). Segway® Fungicide SC treatments starting in March, April, and May, or before soil temperatures reach 26 °C, resulted in improved turfgrass quality and reduced disease severity by early June when compared to the treatments starting in June and July, or after soil temperatures increased above 25 °C (Figure 1). On the last rating date (July 10), treatments 1-3 each received ratings with an average of a 72% reduction in disease severity when compared to treatment 5. Treatments 1 through 3 limited disease severity to about 5% throughout the entire trial period (Figure 2). Although treatment 4 was initiated on June 4, it achieved the same level of disease suppression as treatments 1-3 by the end of the trial period. Treatment 5 did not reduce disease severity below 10%, and therefore suggests that Segway® Fungicide SC applications should be initiated no later than when soil temperatures reach 26 °C.

Authors:

Halle D. Hampy and James P. Kerns,
Department of Entomology and Plant Pathology,
North Carolina State University
Raleigh, NC 27695.

Harvest aids for improved Bermudagrass sod shelf-life and transplantation success

Minaev, N., J.D. McCurdy, M. Tomaso-Peterson, B.R. Stewart, T.C. Barickman, D. Chesser and W. Lowe

Introduction

Shelf-life and transplant success of sodded and sprigged turfgrasses are negatively affected by disruptive harvest techniques and post-harvest handling/storage conditions. Two primary examples include internal heating of "sod masses", including palleted sod or stored sprigs, and improper or delayed irrigation upon installation. Air and light limitations trigger multiple processes that may lead to poor transplant success, such as increased respiration and metabolism of stored carbohydrates[1] and internal heating due to activity of anaerobic microorganisms[2,3]. Research has linked use of certain plant growth regulators to increased sod shelf-life[4,5,6]. Some common fungicides are also thought to increase sod health after harvest[7]. The combination of the succinate dehydrogenase inhibiting fungicide fluxapyroxad and the quinone outside inhibiting fungicide pyraclostrobin has been linked to the protection of newly sprigged ultra-dwarf bermudagrass greens in un-published research and trade journals[8,9,10]. This combination has also been demonstrated in non-peer reviewed research to increase St. Augustinegrass root growth[11].

Materials and Methods

Our research objective was to evaluate effects of several commercially available fungicides, a bio-nutritional experimental plant extract, and a commonly used plant growth regulator on sod shelf-life and transplantation success.

Field research was conducted within a randomized complete block design (4 blocks) with two replications (in 2018 and 2019) on 'Latitude 36' hybrid Bermudagrass [*Cynodon dactylon* (L.) Pers. × *Cynodon transvaalensis* Burtt Davy] established from sprigs in June of 2017. Field research was conducted at the Mississippi State University R.R. Foil Plant Science Research Center near Starkville, MS. Experimental units were 1 × 3 m. The study evaluated effects of the following treatments: experimental bio-nutritional plant extract ACA-3434 (9.6 L of product ha^{-1}), fluxapyroxad + pyraclostrobin (257.1 + 512.9 g ai ha^{-1}), fluopyram + trifloxystrobin (163.4 + 263.6 g ha^{-1}), azoxystrobin (6.1 g ha^{-1}), and trinexapac-ethyl (96 g ha^{-1}). Treatments were applied in a water carrier volume of 561 L ha^{-1} via a CO_2 pressurized backpack sprayer 25 and 4 days prior to harvest. Upon harvest, these treatments and a nontreated check were stored at ambient field temperature (28 °C average). A second nontreated check was also stored at 4 °C, further referred to as "refrigeration". An additional treatment consisted of fluxapyroxad + pyraclostrobin applied immediately after sod installation and again 22 days later.

Sod (40 × 50 cm rectangles) was harvested at a soil depth of 2.5 cm using a Ryan walk-behind sod harvester (Schiller Grounds Care, Inc. Johnson Creek, WI, USA), stacked to a height of 12 layers and either left in the field or refrigerated for 70 hours. Internal sod temperature was monitored by thermocouples inserted into the center of each sod mass. Campbell Scientific CR1000 (Campbell Scientific Inc., Logan, UT) loggers were used to record the data.

Sod was installed on a prepared native soil that had been sterilized three weeks prior to installation with dazo-

1 DARRAH, C.H., and A.J. POWELL., 1977: Post-harvest heating and survival of sod as influenced by pre-harvest and harvest management. Agron. J. 69:283–287.

2 PAHLOW, G., R.E. MUCK, F. DRIEHUIS, S.J.W.H.O. ELFERINK, and S.F. SPOELSTRA, 2003: Microbiology of ensiling. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. Silage Science and Technology, Agronomy Monograph no. 42:31–93.

3 WATSCHKE, T.L., R.E. SCHMIDT, and R.E. BLASER, 1970: Responses of some Kentucky bluegrasses to high temperature and nitrogen fertility. Crop Sci. 10:372–376.

4 ZHANG, X., E. H. ERVIN, and R. E. SCHMIDT, 2003: Seaweed extract, humic acid, and propiconazole improve tall fescue sod heat tolerance and posttransplant quality. HortScience 38(3): 440–443.

5 HECKMAN, N.L., R.E. GAUSSOIN, and G.L. HORST, 2001a:. Multiple trinexapac-ethyl applications reduce Kentucky bluegrass sod storage temperatures. HortTechnology 11(4): 595–598.

6 HECKMAN, N.L., R.E. GAUSSOIN, G.L. HORST, and K.W. FRANK, 2001b: Storage and handling characteristics of trinexapac-ethyl treated Kentucky bluegrass sod. HortScience 36(6):1127–1130.

7 GOATLEY, J.M., and R.E. SCHMIDT, 1991: Biostimulator enhancement of Kentucky bluegrass sod. Hort. Sci. 26:254–255.

8 LEWIS, C., 2017: Boosting plant health on baby greens. Golfdom online magazine. http://www.golfdom.com/boosting-plant-health-on-baby-greens/

9 PERSONAL COMMUNICATION, 2017:. M. Grant. Sod Solutions Producer Field Day, Mississippi State University, Mississippi.

10 PERSONAL COMMUNICATION, 2018: K.M. Kalmowitz. Mississippi State University Turfgrass Research Field Day, Mississippi State University, Mississippi.

11 MARTIN, B, 2016: Disease Management for Turfgrasses. Online publication. http://media.clemson.edu/public/turfschool/Diseases.pdf

met (300 kg ha^{-1}). Sod was installed in the same order that it was harvested as a randomized complete block design. The post-application of fluxapyroxad + pyraclostrobin treatment was applied immediately after installation, then sod and the harvest area were irrigated (20 mm). Irrigation was resumed 24 hours later and continued twice weekly (15 mm each event) until fully recovered from installation. A balanced fertilizer was applied prior to harvest (equivalent to 49 kg N ha^{-1}). Treatment effects on bermudagrass transplantation and harvest area regrowth were assessed visually (% green cover) and by spectral reflectance 1, 4, 7, 14, and 27 days after installation (DAI) using a Holland Scientific RapidScan CS45 handheld crop sensor (Holland Scientific Inc., Lincoln, NE) held 110 cm above and perpendicular to the canopy. Three subsamples were recorded in the center of each experimental unit. Spectral indexes calculated included: normalized difference vegetative index (NDVI), simple ratio vegetative index (RVI), and chlorophyll index – red edge (CI-RE). Root samples (two 10 cm diameter, 10 cm depth plugs per experimental unit) from the refrigerated and nontreated checks, as well as from pre- and post-applied fluxapyroxad + pyraclostrobin treatments, were analyzed 2, 5, and 8 weeks after installation (WAI). For brevity, only root dry mass and root length are discussed. Plugs were washed free of soil, and new root growth was manually separated, patted dry, and frozen (-17 °C). Root architecture was measured using methods described by Begitschke et al.[12]

Vegetative indexes and root analysis were subject to analysis of variance (α=0.05) within SAS (Version 9.4; SAS Institute Inc., Cary, NC) and means were separated within PROC GLM using Student-Newman-Keuls method (α=0.05).

Results and Discussion

Heating in excess of peak ambient daytime temperature did not occur inside sod masses, and no differences in temperature occurred due to treatments, other than that of the refrigerated check. Sod heating is rare but catastrophic in field conditions. We have found it difficult to replicate in controlled settings and suggest that there is room for further research. Failure to internally heat or "ensile" may be due to soil depth harvested (2.5 cm in our study). Prior research indicates that soil separates and isolates layers of vegetative mass and serves as a "heat sink"[2,3,4]. Heckman et al.[5] managed to observe internal heating by stacking forty 102 × 102 cm sod layers, which is a considerably larger sod mass than our own twelve 40 × 50 cm sod layers.

Only refrigeration 1 DAI had higher visual % green cover than the nontreated in both 2018 and 2019. Assessments of % green cover made 4 DAI and later did not differ due to treatment in either 2018 or 2019; however, some variation in vegetative indexes was observed. NDVI values differed between 2018 and 2019 and are presented separately. In 2018, 1, 4, and 7 DAI, refrigeration or pre-application with fluxapyroxad + pyraclostrobin were the only two treatments with greater NDVI values than the nontreated check stored at ambient temperature. NDVI obtained 14 DAI and later was similar amongst all treatments. In 2019, only refrigeration of sod resulted in higher NDVI values 1 and 4 DAI compared to the nontreated.

RVI values did not differ between 2018 and 2019, thus data are pooled across study years. The only difference observed regarding RVI was 1 DAI, when refrigeration resulted in a higher value than all other treatments.

CI-RE values differed between 2018 and 2019 and are presented separately. In 2018, refrigeration resulted in greater CI-RE values than the nontreated, 1 DAI. On 4 DAI, both refrigeration, and pre-application with fluxapyroxad + pyraclostrobin resulted in greater CI-RE than the nontreated. In 2019, the only treatment with greater CI-RE compared to the nontreated was refrigeration, 1 and 4 DAI.

Root dry mass and length differed between 2018 and 2019 and are presented separately. In 2018, 8 WAI, post-application with fluxapyroxad + pyraclostrobin increased root mass compared to pre-application and the nontreated. Refrigeration increased both root dry mass and length compared to the nontreated 2 WAI in 2019.

Our research indicates that refrigeration, or in some cases pre-application with fluxapyroxad + pyraclostrobin fungicide, increased plant health characteristics of transplanted sod in the first days after installation. Their inclusion may be justified in situations when high quality sod with more rapid establishment is required.

Authors:

N. Minaev, J.D. McCurdy
and B.R. Stewart,
Department of Plant and Soil Sciences,
Mississippi State University,

M. Tomaso-Peterson,
Department of Biochemistry,
Molecular Biology, Entomology and
Plant Pathology,
Mississippi State University,

T.C. Barickman, D. Chesser
and W. Lowe,
Department of Agricultural and
Biological Engineering,
Mississippi State University.

[12] BEGITSCHKE, E.G., J.D. McCURDY, T.M. TSENG, T.C. BARICKMAN, and B.R. STEWART, 2018: Preemergence herbicide effects on hybrid Bermudagrass root architecture and establishment. HortScience 53(4):567–572.

Dark green color index to estimate nitrogen status on two turfgrass species

Caturegli, L., M. Gaetani, M. Volterrani, S. Magni, A. Minelli and N. Grossi

Introduction

In recent years digital sensors have been successfully integrated on board Unmanned Aerial Vehicles (UAV) to assess crop vigor, vegetation coverage, and to quantify the "greenness" of foliage as indirect measurements of crop nitrogen status. The classical approach of precision agriculture has involved the use of multispectral sensors onboard UAV and the development of numerous vegetation indices associated with vegetation parameters, such as the mostly used Normalized Difference Vegetation Index (NDVI)[1,2]. However, the main negative issue when dealing with multi and hyper-spectral reflectance measuring tools is their high cost and complexity from the operational point of view. As a low-cost alternative, vegetation indices derived from Red Green Blue (RGB) cameras have been employed for remote sensing assessment, providing data on different stress conditions and species[3]. Digital images record information as amounts of RGB light emitted for each pixel of the image; however, the intensity of red and blue often alters how green an image appears. To simplify the interpretation of digital color data, recent studies have suggested converting RGB values to the more intuitive Hue, Saturation, and Brightness (HSB) color spectrum, and then into a single measure of dark green color, the Dark Green Color Index (DGCI). To facilitate the DGCI acquisition, also a smartphone application called FieldScout GreenIndex+ Turf (Spectrum Technologies, Inc., Aurora, IL, USA -Spectrum Technologies, Inc. 2018) has been developed and tested[4]. The application (APP) captures images with a smartphone or tablet, calculates the DGCI, and shows a turfgrass quality visual rating[5].

In this study NDVI acquired by a ground-based handheld crop sensor and by a multispectral camera mounted on board of a UAV have been compared with DGCI calculated from images taken with a commercial digital camera on board of a UAV, trying to quantify the color of turfgrass that had received different nitrogen (N) rates.

The objectives of the trial were to study an affordable easy-to-use tool evaluating the relationship among NDVI, DGCI and leaf nitrogen content on turfgrass.

Materials and Methods

The trial was carried out in July 2017 in S. Piero a Grado, Pisa, at the Centre for Research on Turfgrass for Environment and Sports (CeRTES) of the Department of Agriculture, Food and Environment of the University of Pisa (43°40'N, 10°19'E, 6 m. a. s. l). The turfgrasses selected for the study were a mature turfgrass stand of bermudagrass (*Cynodon dactylon* [L.] Pers. (Linnaeus Persoon) variety dactylon x *Cynodon transvaalensis* Burtt-Davy) cultivar (cv) 'Patriot' and tall fescue (*Schedonorus phoenix* [Scop.] (Scopoli) Holub) cv 'Grande'. In order to create a linear nitrogen gradient, on June 2017 fertilization was carried out applying ammonium sulphate (21-0-0) with a rotary spreader. For tall fescue 8 nitrogen (N) rates, from 0 to 210 kg ha^{-1} with increases of 30 kg ha^{-1}. For bermudagrass, which tolerates higher doses of fertilizer, 11 N rates were applied, from 0 to 300 kg ha^{-1} with increases of 30 kg ha^{-1}. The plot size was 3 m × 3 m, with 3 replications. In the entire experimental area identical maintenance practices were applied. The ground-based instrument used to acquire NDVI values was a Handheld Crop Sensor (HCS) (GreenSeeker, Model HSC-100, Trimble Navigation Unlimited, Sunnyvale, CA) while the remote sensed readings were collected with a UAV which was a VTOL (Vertical Take Off and Landing) DJI s900 hexacopter (DJI, Shenzhen, China) equipped with a digital commercial camera Sony Nex 5 (Sony, Surrey, United Kingdom) and a lightweight multispectral sensor MAIA S2 (SAL Engineering, Modena Italy; EOPTIS, Trento, Italy). In the same day as the ground NDVI and the NDVI by the multispectral camera readings were acquired, the digital camera recorded UAS derived imagery RGB images above the interested area, always in a zenithal plane. To simplify the interpretation of data, RGB values were converted into HSB values, using the method suggested by [5], to finally calculate the DGCI. DGCI value is on a scale from 0 (very yellow) to 1 (dark green)[6]. DGCI was calculated as:

$$DGCI = [((Hue) - 60)/60 + (1 - (Saturation)) + (1 - (Brightness))]/3$$

[1] JIANG, Y. and R.N. CARROW, 2007: Broadband spectral reflectance models of turfgrass species and cultivars to drought stress. Crop Science 47: 1611-1618.

[2] CATUREGLI L., M. CORNIGLIA, N. GAETANI, S. GROSSI, M. MAGNI, L. MIGLIAZZI, M. ANGELINI et al., 2016: Unmanned Aerial Vehicle to estimate nitrogen status of turfgrasses. PLOS ONE. 11(6), e0158268. doi:10.1371/journal.pone.0158268.

[3] VERGARA-DÍAZ, O., M.A. ZAMAN-ALLAH, B. MASUKA, A. HORNERO, P. ZARCO-TEJADA, B.M. PRASANNA, J.E. CAIRNS and J.L. ARAUS, 2016: A novel remote sensing approach for prediction of maize yield under different conditions of nitrogen fertilization. Frontiers in Plant Science 7:666. doi: 10.3389/fpls.2016.00666.

[4] XIONG, X., G.E. BELL, J.B. SOLIE, M.W. SMITH and B. MARTIN, 2007: Bermudagrass seasonal responses to nitrogen fertilization and irrigation detected using optical sensing. Crop Science 47 (4): 1603-1610.

[5] KARCHER, D.E. and M.D. RICHARDSON, 2003: Quantifying turfgrass color using digital image analysis. Crop Science 43: 943-951.

[6] RHEZALI, A. and R. LAHLALI, 2017: Nitrogen (N) mineral nutrition and imaging sensors for determining N status and requirements of maize. Journal of Imaging 3(4): 51.

The correlations between the two different NDVI reading methods (ground-based sensing with a HCS and remote sensing with UAV) and DGCI were studied using CoStat software (CoHort, Monterey, CA, USA).

Results and Discussion

Comparing DGCI and all the measured parameters in bermudagrass, the index was significantly correlated with Color intensity, Quality and Plant Water Content (PWC) with *r* values ranging between 0.83 for color intensity and 0.84 for turfgrass quality and PWC (Table 1). Observing the correlations, also in tall fescue DGCI was highly correlated with all the measured parameters with *r* values ranging between 0.92 for DGCI-Quality, 0.98 for DGCI-PWC, and 0.95 for DGCI-turfgrass color.

Previous reports by [7] and [8] also indicated this trend of values between DGCI and turfgrass quality and turfgrass color. As in our study also in the report by[8], the association between DGCI and turfgrass quality in tall fescue showed higher *r* values than the same association in bermudagrass. As for the turfgrass color, [7] also studied the relationship between visual color rating and DGCI, with higher Pearson correlation coefficient in tall fescue than bermudagrass. Moreover, as also demonstrated by [7], DGCI values were linearly associated with both NDVI (GreenSeeker and UAV) in both species and with clippings N content.

Thus, DGCI values could predict the average nitrogen concentrations of tall fescue and bermudagrass hybrid clippings in different plots and with different application rates. The close association between DGCI and leaf nitrogen therefore provided an additional tool for the assessment of leaf nitrogen content. Our research was consistent with previous work by [5] who found that DGCI values were able to differentiate among turfgrass cultivars receiving various N treatments. Frequently raters ranked the turf plots similarly although differences in color existed. Therefore, visual color rating remains a valid evaluation tool if data are not compared across raters. However, the accuracy of DGCI, as demonstrated in previous studies, enables researchers to record reflected turfgrass color on a standardized scale rather than using arbitrary rating values.

More research is required on this technology and on the Smartphone APP FieldScout GreenIndex+ Turf (Spectrum Technologies, Inc., Aurora, IL, USA) to study and overcome possible discrepancies between the APP and the Smartphone camera.

r	Color intens. (1-9)	Quality (1-9)	PWC (%)	NDVI GS	NDVI UAV	DGCI
a) Bermudagrass						
N clipping (%)	0.97	0.97	0.95	0.94	0.92	0.86
Color intens. (1-9)	-	0.94	0.99	0.94	0.94	0.83
Quality (1-9)	-	-	0.97	0.97	0.94	0.84
PWC (%)	-	-	-	0.92	0.92	0.84
NDVI GS (780,660)	-	-	-	-	0.96	0.91
NDVI UAV (830,660)	-	-	-	-	-	0.85
b) Tall fescue						
N clipping (%)	0.99	0.99	0.99	0.95	0.94	0.95
Color intens. (1-9)	-	0.99	0.99	0.96	0.95	0.95
Quality (1-9)	-	-	0.98	0.94	0.93	0.92
PWC (%)	-	-	-	0.98	0.98	0.98
NDVI GS	-	-	-	-	0.99	0.95
NDVI UAV	-	-	-	-	-	0.96

Tab. 1: Pearson product-moment correlation coefficients (*r*) among Clipping nitrogen content, Color intensity , Quality, Plant Water Content (PWC), NDVI measured with a handheld crop sensor (GreenSeeker – GS) and NDVI measured with multispectral camera mounted on an unmanned aerial vehicle (UAV) and dark green color index (DGCI) on a) bermudagrass; b) tall fescue. For each species correlation coefficients are calculated across all entries.

Authors:
Lisa Caturegli*, Monica Gaetani, Marco Volterrani, Simone Magni and Nicola Grossi,
Department of Agriculture, Food and Environment,
University of Pisa, Pisa, Italy,

Alberto Minelli,
Department of Agricultural and Food Sciences,
University of Bologna, Bologna, Italy.

*Corresponding author E-Mail:
lisa.caturegli@gmail.com

[7] ZHANG, C. and J.M. KOVACS, 2012: The application of small unmanned aerial systems for precision agriculture: a review. Precision Agriculture 13: 693-712.

[8] LEINAUER, B., D.M. VANLEEUWEN, M. SERENA, M. SCHIAVON and E. SEVOSTIANOVA, 2014: Digital image analysis and spectral reflectance to determine turfgrass quality. Agronomy Journal 106 (5): 1787-1794.

Optimizing turfgrass fertilization to reduce nitrogen losses through leaching

Côté, L and G. Grégoire

Introduction

Turfgrass-covered surfaces provide many benefits such as absorption of contaminants and reduction of urban heat islands[1], but some question the environmental impacts of different practices related to their maintenance, such as nutrient losses from fertilizers[2]. Several Canadian municipalities have adopted measures to control the use of turfgrass fertilizers on their territories, but these measures are generally incomplete and sometimes even inadequate[3]. In a previous research, we showed that phosphorus losses in runoff were lower in fertilized plots compared to unfertilized plots when following good fertilization practices[4]. However, in this same experiment, losses in nitrate-N through leaching were higher in fertilized plots compared to the unfertilized control. While these losses were relatively small (between 2-4% of the applied N), we hypothesized they can be further reduced by controlling different factors influencing N losses, such as source, rate and fractioning[5,6,7].

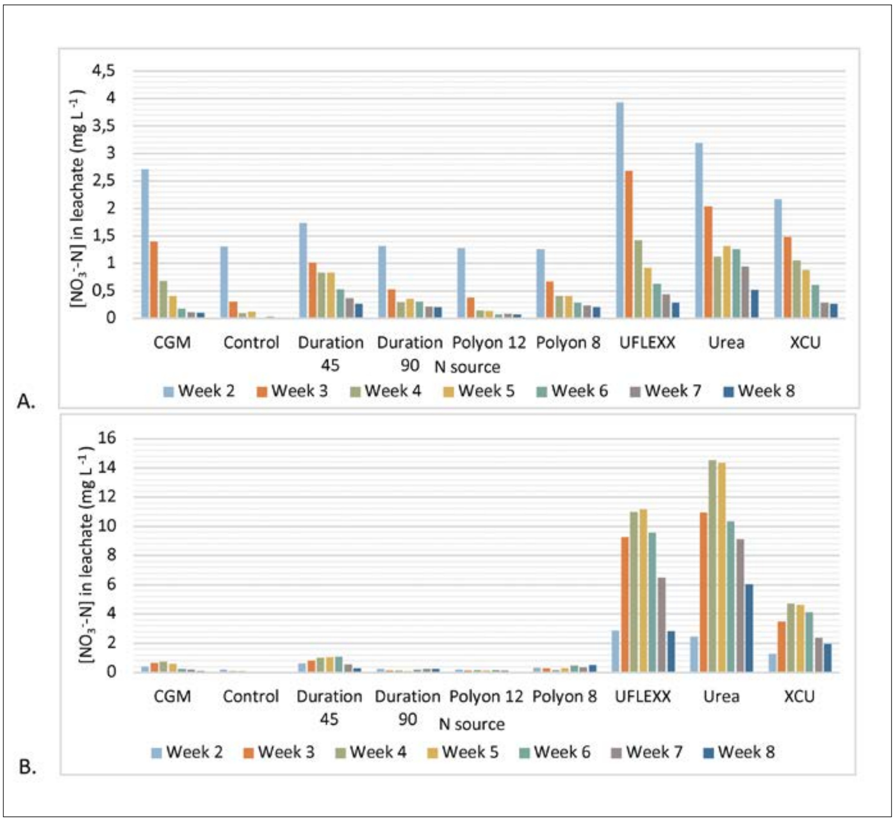

Fig. 1: Average nitrate-N concentration (in mg L^{-1}) in leachate following the application of different N sources to turf regardless of the rate and fractioning during seven weeks in the loam (A) and in the sand (B).

Materials and Methods

A greenhouse experiment was initiated in February 2019 in which Kentucky bluegrass (*Poa pratensis* L.) was seeded in pots lined with a plastic bag (TP49CH mini-forestry pots, Stuewe & Sons, inc., Tangent, Oregon, USA) either on a sandy (80% sand, 20% peat moss) or a loamy (St-Nicolas schist loam) soil. After a 3 week grow-in period, different fertilization treatments were applied in a factorial experiment consisting of eight fertilizers sources (urea, Polyon® 8 and 12 weeks release, Duration® 45 and 90 days release, XCU®, corn gluten meal (CGM) and UFLEXX®) and five nitrogen rates (25, 50, 100, 150 and 250 kg N ha^{-1} yr^{-1}) split in either 1 or 2 applications. Thus, a total of 84 different treatments (8 fertilizer sources X 5 rates X 2 fractioning,

[1] STEINKE, K., E.H. ERVIN, F.R. HIGGINSON and P.E. McMAUGH, 2013: Turfgrass benefits and issues. In: Turfgrass:biology, use, and management. Madison, WI, American Society of Agronomy.

[2] LAWNICZAK, A.E., J. ZBIERSKA, B. NOWAK, K. ACHTENBERG, A. GRZEŚKOWIAK and K. KANAS, 2016: Impact of agriculture and land use on nitrate contamination in groundwater and running waters in central-west Poland. Environmental Monitoring and Assessment, 188(3): 172.

[3] BOUCHARD, K, 2011: Gestion des engrais et des pesticides au Québec: Études de cas et perspectives. Centre Universitaire de Formation en Environnement, Université de Sherbrooke. 79p.

[4] GRÉGOIRE, G., C. BAJZAK and Y. DESJARDINS, 2017: Projet de recherche sur l'impact de la fertilisation des pelouses sur les pertes en éléments nutritifs par lessivage et ruissellement. Centre de recherche en Horticulture Faculté des Sciences de l'Agriculture et de l'Alimentation, Université Laval, 33 p.

[5] GUILLARD, K. and K.L. KOPP, 2004: Nitrogen fertilizer form and associated nitrate leaching from cool-season lawn turf. Journal of Environmental Quality, 33: 6.

[6] BARTON, L. and T.D. COLMER, 2006: Irrigation and fertiliser strategies for minimising nitrogen leaching from turfgrass. Agricultural Water Management, 80(1-3): 160-175.

[7] CAREY, R.O., G.J. HOCHMUTH, C.J. MARTINEZ, T.H. BOYER, V.D. NAIR, M.D. DUKES, G.S. TOOR, A.L. SHOBER, J.L. CISAR, L.E. TRENHOLM and J.B. SARTAIN, 2012: A review of turfgrass fertilizer management practices: Implications for urban water quality. Hort.Technology 22(3): 280-291.

plus 4 unfertilized control) were tested as a completely randomized design with four replicates, and two 8-week runs were performed for each soil texture. Turfgrass was irrigated once per week with 250 ml (for sand) or 350 ml (for loam) of water per pot, in order to induce a leaching event. Leachate was collected in a 50 ml sterile polypropylene centrifuge tube (VWR™, Radnor, Pennsylvania, USA) fixed to the bottom of each pot and transferred into a 2 ml plastic tube (Simport Scientific, Beloeil, Quebec, Canada). Leachate content in NO_3-N was then determined by the second derivative visible spectroscopy technique for nitrate[8] using a Epoch™ 2 Microplate Spectrophotometer (BioTek Instruments inc., Winooski, Vermont USA). Turfgrass visual quality was evaluated weekly on a 1 to 9 scale (1= low quality, 9 = high quality, 6 = acceptable quality). Finally, at the end of each run, above-ground biomass was harvested and dried at 60 °C for 48 hours in order to determine total N content of turf with an adaptation of Kjeldahl procedure[9]; total nitrogen content of each sample was measured by colorimetry.

Results and Discussion

Our results show that, in both soil types, using only one application (instead of 2) and applying higher N rates resulted in higher NO_3-N losses through leaching (data not shown). Effect of treatments were similar for both soil types, but NO_3-N losses were generally higher in the sand. Regardless of the treatment, losses were higher at the beginning of the loam experiment, probably because of rapid N mineralization from the organic matter caused by soil manipulation. However, by the third week, losses were lower than 1 mg L^{-1} of NO_3-N for all treatments except for urea, UFLEXX® and XCU®. In addition to these high losses (up to almost 4 mg L^{-1}), urea and UFLEXX® caused turf phytotoxicity at rates from 100 to 250 kg N ha^{-1} (data not shown). UFLEXX® and urea also resulted in phytotoxicity in the sand in addition to resulting in the highest NO_3-N losses (between 11 to 14 mg L^{-1}) which exceeded the 10 mg L^{-1} threshold for NO_3-N concentration allowed in potable water[10]. Although Duration 90® and Polyon 12® generated low NO_3-N losses in the sand, they also resulted in unacceptable visual quality throughout the experiment. Polyon 8® and Duration 45® both resulted in acceptable turf quality in the sand, but only at the high nitrogen rate (250 kg N ha^{-1}). Turfgrass grown in sand and fertilized with corn gluten meal at rates from 100 to 250 kg N ha^{-1} had relatively low NO_3-N losses combined with a high visual quality. Few differences in turf quality were observed in the loam, with most treatments resulting in acceptable quality. The 20 best fertilization treatments for each soil type will be selected for a subsequent 20-week trial in order to measure long-term NO_3-N leaching losses. Results from this experiment will help turfgrass managers select the optimal fertilization strategy for their soil type in order to obtain a high-quality surface while reducing underground water contamination by nitrogen from fertilizers.

Authors:

Laura Côté and Guillaume Grégoire,
Centre de recherche en innovation sur les végétaux,
Département de phytologie,
Université Laval, Québec, Canada.

[8] FERREE, M.A. and R.D. SHANNON, 2001: Evaluation of a second derivative UV/visible spectroscopy technique for nitrate and total nitrogen analysis of wastewater samples. Water Research, 35(1): 327-332.

[9] HACH, C.C. et al., 1985: A powerful kjeldahl nitrogen method using peroxymonosulfuric acid. Journal of Agricultural and Food Chemistry 33(6): 1117-1123.

[10] SANTÉ CANADA, 2013: Le nitrate et le nitrite, Gouvernement du Canada. Recommandations pour la qualité de l'eau potable au Canada: document technique, 131 p.

Nitrogen rate, irrigation and rainfall impacts on groundwater nitrate levels in sandy coastal golf courses

Petrovic, A.M., T.C. Cambareri, L.J. Barnes and S. Cohen

Introduction

There has been a serious concern over fertilizer nitrogen (N) applied to turfgrass areas affecting groundwater quality in sandy coastal areas since the 1970's[1]. Since the 1970's there has been an extensive amount of small-scale research studies[2] that determined the major factors that contribute to excessive nitrate-N leaching from turfgrass ecosystems including: soil texture, soluble N application rate, irrigation and application season. There are, however limited data on large scale groundwater monitoring of turfgrass sites such as golf courses that are related to management inputs including N application, irrigation amounts and climatic factors such as evapotranspiration rates (ET) and precipitation. There also have been land use regulations limiting the amount of fertilized turfgrass in coastal area in the USA like Cape Cod, MA and Long Island, NY. The regulations assume a linear relationship between the amounts of N applied and amount of N leached. The purpose of this study is to evaluate the long-term impact of yearly variations in N application rate, irrigation amounts and seasonal precipitation on groundwater quality on golf courses in critical groundwater recharge areas prone to nitrate and pesticide contamination.

Materials and Methods

Two golf courses, The Bridge (TB) and Sebonack Golf Club (SGC), in this study are in eastern Long Island, NY with systematic groundwater monitoring for NO_3-N and pesticides as part of the permitting and approval process. Each golf course is required to follow best management practices (BMP) to reduce the likelihood of groundwater contamination including limitations on amount, rate, source and timing of N applications as well as controlled irrigation based on on-site ET measurements. Both sites are located on the Laurentide terminal moraine comprised of moderately permeable sandy till, poorly sorted mixture of clay, sand, gravel and boulders transitioning to a well-sorted highly permeable deposit of fine to coarse sands. The hydraulic conductivity ranges from 40 to 90 m/d. TB is located high on the moraine with a depth to groundwater of approximately 45 m and the SGC is located on a lower peninsula abutting the ocean with a depth to groundwater of approximately 8 m. Greens and tees are constructed with USGA recommended sand-peat rootzone. Fairways (Carver sand and loamy sand) were amended with onsite composted organic debris from land clearing (SGC) or composted yard waste (TB). The monitoring wells were placed down gradient of large fertilized areas and the NO_3-N data used in this study is from 7 wells at TB and 5 wells at SGC. The monitoring frequency was initially quarterly but is now semi-annual. Monitoring commenced during construction, 2001 at TB and in 2005 at SGC. Groundwater well samples are iced, overnight delivered to the certified testing laboratory (initially Under Writers Laboratory, now Eurofin Laboratory of South Bend, IN) and tested for NO_3-N and TKN using USEPA standard methods, only NO_3-N data will be discussed. Each golf course applied low single rate N application (5 kg/ha in some cases) of controlled release N sources and/or natural organic fertilizers. Irrigation was based on daily estimated ET from onsite weather data collected and adjusted for larger rainfall events >19 mm for net ET. With very few exceptions, yearly irrigation was always < net ET. Yearly irrigation use varied slightly and was not related to NO_3-N levels observed in groundwater monitoring wells.

Results and Discussion

The N fertilization program at TB on 16.6 ha was initially high in the first 4 yrs (maximum of 3,931 kg), to a low of 746 kg with a 17 yr average of 1,500 kg or 90 kg N/ha/yr on greens/tees and fairways. SGC fertilization program on 22.7 ha (not including greens are lined and not linked to groundwater) had its highest annual N application of 3,120 kg to a low of 1,151 kg with a 13 yr average of 2,107 kg or 93 kg N/ha/yr on tees and fairways. Even with a two to four-fold difference in the yearly N application rate (Figure 1), there is no relationship between the total yearly N applications and the yearly average NO_3-N concentration in groundwater monitoring wells at both golf courses (R^2=0.0095).

In general, SGC had both higher N applications and higher NO_3-N concentrations in groundwater than TB but now each is below the target goal of 2 mg/L of NO_3-N. Others have found an increase of from 55% to 6-fold[3] in the amount of applied N that leached when N rates were tripled depending on soil to a 7-fold[4] increase when N rates were 4 times higher. These studies applied annual N rates 3 to 4 times higher than in our study while also using highly water-soluble sources. The linear regression lines in Figure 1 show how in one

[1] PETROVIC, A.M., 1990: The fate of nitrogenous fertilizers applied to turfgrass. J. Environmental Quality 19:1-14.

[2] PETROVIC, A.M. and Z.M. Easton, 2005: The Role of Turfgrass Management in the Water Quality of Urban Environments. Intern. Turfgrass Soc. Res. J. 10:55-69.

[3] BRAUEN, S.E. and G.K. STAHNKE, 1995: Leaching of nitrate from sand putting greens. USGA Green Sec. Rec. 33(1): p. 29-32.

[4] KOPP, K.L. and K. GUILLARD, 2005: Clipping contributions to nitrate leaching from creeping bentgrass under varying irrigation and N rates. Int. Turfgrass Soc. Res. J. 10(Part 1): p. 80-85.

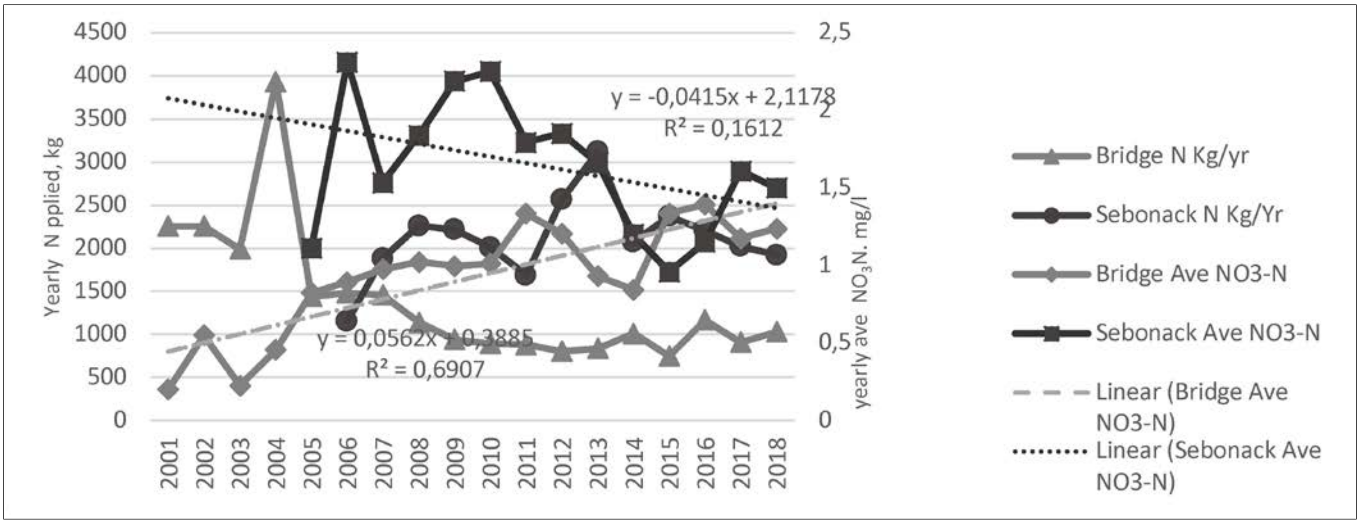

Fig. 1: Yearly average groundwater NO_3-N conc (mg/L) verses yearly fertilizer N application rate (kg/yr).

case (TB) there is a slight increase in NO_3-N levels in groundwater (R^2=0.69) over time but not at the other course. Multiple regression analysis of TB results indicates a relationship between NO_3-N concentration and time and mass of applied N fertilizer: [N] = 1.76 – 0.0006063 x N Mass – 0.114 x Yr (1 through 18) + 0.000104 x N Mass x Yr (R^2=0.74; p value=0.0004; F ratio = 12.5). The Bridge data did not provide a satisfactory relationship among the same parameters; rather, there were acceptable relationships between the dependent variable, nitrate-N, and the two pairs of independent variables, mass of N applied and precipitation and time (number of years) and precipitation. In some cases, it has been shown during the establishment phase to have the greatest amount of NO_3-N leaching[5]. However, if high rates of N (245 kg N/ha/yr) were applied in 12 yr study, more NO_3-N leaching occur with time[6] than at a lower rate. The 7-month growing season precipitation amounts followed the NO_3-N levels in the groundwater monitoring wells at SGC (Figure 2).

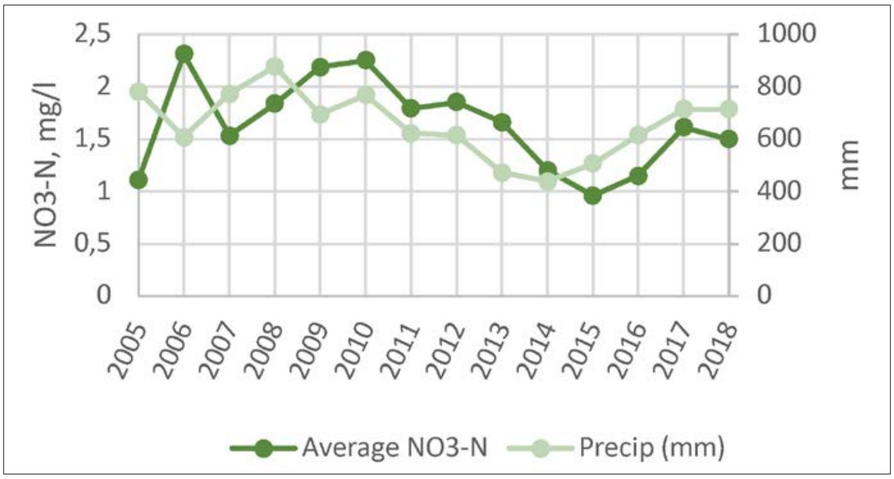

Fig. 2: Precipitation (mm) over 7 month Growing Period and Average Nitrate-N Concentrations (mg/l) by Year at the Sebonack GC.

The results of this study clearly show that on golf courses in sandy critical groundwater recharge areas prone to nitrate and pesticide contamination that follow BMP for N fertilization, the amount of N applied is not related to NO_3-N levels in groundwater. Growing season rainfall amounts more closely followed NO_3-N levels in groundwater, thus abnormally high rainfall can result in higher NO_3-N levels in the groundwater. Implementing fertilizer BMP can be very effective in protecting groundwater quality.

Authors:

A. Martin Petrovic,
Cornell University,

Thomas C. Cambareri,
Sole Source Consulting LLC,

La Jan Barnes and Stuart Cohen,
Environmental & Turf Services, Inc.

[5] EASTON, Z.M. and A.M. PETROVIC, 2004: Fertilizer source effect on ground and surface water quality in drainage from turfgrass. J. Environ. Qual. 33(2):p. 645-655.

[6] FRANK, K.W., J.R. CRUM, R.N. CALHOUN and K.M. O'REILLY, 2006: The fate of nitrogen applied to a mature Kentucky bluegrass turf. Crop Sci. 46(1): p. 209-215.

Validation of the MLSN guideline for soil phosphorus on golf course putting greens

Hesselsøe, K.J., K. Sintorn, K. Donkers, N. Dokkuma, Y. Chen, T. Pettersen, W. Pramässing, M. Woods, D. Cleaver, A.F. Øgaard, T. Krogstad and T.S. Aamlid

Introduction

Eutrophication of freshwater ponds and lakes caused by excessive phosphorus (P) in leakage or surface runoff and the fact that P is the plant nutrient of which the world's mineral resources are most limited, call for less and more targeted use of P in turfgrass systems.

Currently, there is no European standard for turfgrass fertilization as a function of the soil's content of plant available P. Some consultants and greenkeepers have adopted the American SLAN-recommendation (Sufficiency Level of Available Nutrient) which prescibes soil-P levels similar to those recommended for agricultural crops. The SLAN-guideline for turfgrass recommends to keep soil P level above 54 mg P/kg dry soil using Mehlich-3 extraction[1].

Minimum Level of Sustainable Nutrition (MLSN)[2] is a method for soil test interpretation and fertilizer recommendations based on data from more than 17000 individual soil samples analyzed by the Mehlich-3 soil extraction method, taken around the world from good performing turfgrass areas. Because all these samples were from well performing turf, the expectation were, that the nutrient levels in these soils were sufficient. The data were filtered to remove soils with high CEC (which is not so relevant for P since it is taken up as anions) and high or low pH to reach a total of approx. 3500 soil tests. MLSN guidelines were developed by fitting a log-logistic distribution to these data. For P, the MLSN guideline in the range 18-21 mg P/kg dry soil was selected as the value at which the probability for a random sample having a value less than or equal to this value is less than 10%.

Scandinavian Precision Fertilization[3] (SPF) is a method for turfgrass fertilization widely used at golf courses in the Nordic countries. This method focuses on fertilizing with all nutrients at a constant ratio to N equivalent to that found in plant tissue and disregards soil analyses. For P the recommendation is to apply 12% of the annual N input regardless of soil P level.

Although this is a safe method, it is likely to result in redundant P applications, and thus environmental and economic losses, on soils high in plant available P.

The objective of this research was to compare P-fertilization of golf course putting greens according to SLAN, MLSN and SPF guidelines. Specifically, we want to explore in five countries representing various climates, soils, turfgrass species and management practices, the implications for turf quality and fertilizer costs over a four year period by switching from SLAN or SPF to MLSN fertilization.

Materials and Methods

The field experiments were conducted on: a red fescue (*Festuca rubra*)/colonial bentgrass (*Agrostis capillaris*) green at Princenbosch Golf Club in The Netherlands, an annual bluegrass (*Poa annua*)/creeping bentgrass (*Agrostis stolonifera*) green at Falkenberg Golf Club in Sweden, a creeping bentgrass green at Jingshan Lake Golf Club in Beijing, China, an annual bluegrass/creeping bentgrass green at Dütetal Golf Club in Germany and a creeping bentgrass green at the NIBIO turfgrass research centre Landvik in Norway. The trials were laid out in June 2017 (Dütetal GC: December 2017) on greens with relatively low P values (Table 1). The experimental design was a 4 x 4 Latin square with the following treatments: (1) No P fertilization; (2) Monthly P fertilization according to MSLN guidelines; (3) Monthly P fertilization according to SPF guidelines and (4) Monthly P fertilization according to SLAN guidelines. The monthly inputs of P were given as liquid applications of triple superphosphate (triple superphosphate Opti-P 0-20-0; Yara, Norway) in an application volume of 800 L/ha. For June-October 2017 the monthly inputs of P in treatments 2 and 4 were calculated from the soil analyses taken in June 2017 (Table 1); in later years, the monthly inputs April – October were calculated from the soil samples taken in the end of the previous growing season in November (at least four weeks after the latest application of P). All soil analyses were shipped to a soil lab at the Norwegian University of Life Sciences. The annual P-rates in treatments 2-4 were further adjusted to account for the annual removal of P in turfgrass clippings, assuming a P/N ratio of 12% and that the entire N input was removed in clippings. The entire experimental area was at least monthly fertilized with a NK fertilizer, also providing Mg, Ca, S and micronutrients. The annual N rate varies from 6 g N/m^2 on the fescue green in the Netherlands to 21 g N/m^2 on the annual bluegrass/creeping bentgrass greens in Sweden and Germany.

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[1] CARROW, R.N., L. STOWELL, W. GELERNTER, S. DAVIS, R.R. DUNCAN and J. SKORULSKI, 2004: Clarifying soil testing: III. SLAN sufficiency ranges and recommendations. Golf Course Management 72(1): 194-198.

[2] WOODS, M.S., L.J. STOWELL and W.D. GELERNTER, 2014: Just what the grass requires. Using minimum levels for sustainable nutrition. Golf Course Management 82(1): 132-136, 138.

[3] ERICSSON, T., K. BLOMBÄCK and A. KVALBEIN, 2010: Precision fertilization – from theory to practice. Handbook. www.sterf.org. Accessed 16 December 2019.

Experimental site	Green type	Start values (0-20 cm soil depth)	
		pH (H_2O)	Soil P value (Mehlich-3) mg P/kg dry soil
Princenbosch, Netherlands	USGA	6.3	6
Falkenberg, Sweden	Push-up	6.0	33
Jingshan Lake, China	USGA	8.3	6
Dütetal, Germany	USGA	6.7	15
Landvik, Norway	USGA	5.9	26

Tab. 1: Experimental sites, green types and start values for soil pH and P-values.

Daily maintenance, including application of NK fertilizer was conducted by the local field host/golf club. A scientist/agronomist from the project group visits the trials regularly and is responsible for P-fertilization of individual plots, monthly visual assessments and annual sampling and shipment of soil samples for analysis for P. Assessments includes density, coverage, color, overall turfgrass quality and root development. Turfgrass root development are measured as the length of intact hanging cores pulled out with a core sampler. The trials will be going on until Nov 2020.

Results and Discussion

The results in turfgrass quality 2017-2019 are preliminary and shows hardly any significant effects. From the growing season 2018 there were tendencies to better turf quality with higher P inputs at Landvik, Norway and at Falkenberg, Sweden, but no effects at the three other sites. At Landvik the effect was mostly due to a trend to slower reestablishment in the spring and early summer 2018 after reseeding plots without P than with P application after winter kill. Despite the fact that they did not have the lowest soil P values (Table 1), the zero-P plots at Landvik were also the only plots showing tendencies to a dark purple color indicating P deficiency. In some of the other trials the highest P inputs according to SLAN-recommendation tended to favour annual bluegrass relative to creeping bentgrass. Similar effects have been reported in US trials[4]. The effect of P-fertilization on root development showed conflicting results between sites.

From the growing season 2019 we still miss the soil-P analyses. The results in turfgrass quality for 2019 are yet to be analysed statistically, but they show tendencies to more moss without P-fertilizer at Princenbosch in the Netherlands, more *P. annua* with increasing P-rate in Falkenberg, Sweden and slightly deeper roots without P in Dütetal, Germany.

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Authors:

Karin Juul Hesselsøe ,
Trond Pettersen, Anne Falk Øgaard and Trygve S. Aamlid,
Norwegian Institute of Bioeconomy Research (NIBIO),

Kim Sintorn,
Swedish Golf Federation,

Koert Donkers, Niels Dokkuma3,
Netherlands Golf Federation,

Yajun Chen,
Northeast Agricultural University, Harbin, China,

Wolfgang Pramässing,
University of Applied Sciences, Osnabrück, Germany,

Micah Woods,
Asian Turfgrass Center, Bangkok, Thailand,

Dean Cleaver,
Federation of European Greenkeeper Associations (FEGGA),

Tore Krogstad,
Norwegian University of Life Sciences (NMBU).

[4] RALEY, R.B., P.J. LANDSCHOOT and J.T. BROSNAN, 2013: Influence of phosphorus and nitrogen on annual bluegrass encroachment in a creeping bentgrass putting green. Int. Turfgrass Society Research Journal 12: 649-655.

Criteria for identifying ecosystem services on golf courses in Germany

Rosenbusch, J., M. Thieme-Hack and W. Praemassing

Introduction

German golf courses consume 75 hectares of land per course on average[1]. The golf courses do not consist of playing areas only, but new and existing biotope types of various characteristics and values. Golf courses in monotonous landscapes can contribute to a significant landscape enhancement. On German golf courses, on average, more than 50% of the golf course area is not used as playing area[2], but largely represents extensively maintained areas. Nevertheless, the enormous space consumption associated with the establishment of golf courses is viewed critically by the non-golfing public and damages the image of golf in general. The representation of the value of ecosystems can be achieved by applying the ecosystem service concept. By applying this concept, the social value of landscape spaces can be determined and used for public relations.

Materials and Methods

While the classic view of nature already depicts nature as valuable and worth protecting, the focus in ecosystem services is solely on the benefit for humans. The services of ecosystems can be classified into the subcategories basic, supply, regulatory and cultural services due to their properties, their functions and their human uses[3]. Due to the definition ("typing") of various services, these subcategories are referred to as "service types"[4]. Within the framework of the ecosystem service concept, existing services of an ecosystem are first identified before they are measured and evaluated (Figure 1).

Fig. 1: The process sequence within the framework of the ecosystem service concept.

Because basic services guarantee the existence of all other service types, e.g. in the form of ensuring the nutrient cycle as the basis for the formation of vegetation, they are by definition intermediate services[5]. The ecosystem services of the above-mentioned ecosystem service types require a further distinction. Ecosystem service products can be defined as "final ecosystem services"[5]. These represent those services that can be directly enjoyed, consumed or used by humans and which can therefore also be called end products of ecosystems. In contrast, the other services represent intermediate services that contribute to the achievement of the end products. These services are therefore already included in the "final ecosystem services". In addition, the final ecosystem services differ in terms of what their human-friendly benefits affect. The type of service "natural / healthy habitat" includes all final ecosystem services that serve people by providing or improving a healthy habitat. The type of service "ecosystem services as an input factor for market goods" includes final ecosystem services that offer people added value through their economic usability in the form of input factors and production support services. "Directly usable final ecosystem services" ultimately represent all other final ecosystem services that can be enjoyed, used or consumed directly. See Table 1 for a list of final ecosystem services in the spatial scale of a nation. It can later serve as the basis for the identification of ecosystem services on golf courses.

Discussion

Due to the different perspectives of nature considerations, there are differences with the conventional nature conservation idea. If e.g. a particularly rare ecosystem has small impact on human wellbeing (e.g. if it has a high cultural value but cannot be physically reached and experienced) or, vice versa, if an ecosystem has a particularly high social benefit but from a nature conservation perspective, it is usually less worth protecting (e.g. turfgrass areas). There are also differences depending on the geographic location (e.g. landform, height above sea level etc.). For example, in areas with an extreme climate, some ecosystem services are not available or are only weakly available, such as no or only low CO_2 sequestration due to

[1] SCHEFFLER, W., 2016: Von der Sorge um das beste Gruen. Frankfurter Allgemeine Zeitung No. 136, 14. June 2016.

[2] FEDERAL AGENCY FOR NATURE CONSERVATION & GERMAN GOLF ASSOCIATION, 2005: Bundesamt für Naturschutz – BfN und Deutscher Golf Verband e. V. – DGV. Biotopmanagement auf Golfanlagen. Albrecht Golf Verlag, Gräfelfing, Germany.

[3] MILLENIUM ECOSYSTEM ASSESSMENT, 2005: Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

[4] STAUB, C., W. OTT, F. HEUSI, G. KLINGLER, A. JENNY, M. HAECKI, A. HEUSER, 2011: Indikatoren für Ökosystemleistungen – Systematik, Methodik und Umsetzungsempfehlungen für eine wohlfahrtsbezogene Umweltberichterstattung. Bundesamt für Umwelt, Bern.

[5] BOYD, J.W. and H.S. BANZHAF, 2006: What are Ecosystem Services? The Need for Standardized Environmental Accounting Units (January 2006). Resources for the Future, Discussion Paper No. RFF DP 06-02. URL: https://ssrn.com/abstract=892425.

Final ecosystem service	Type of end product	Benefit	Service type
Recreation by hunting, collecting and observing wild species	Final service that can be used directly	Recreation	Cultural
Recreation through urban green and open spaces as well as near and far recreational areas	Final service that can be used directly	Recreation	Cultural
Recreational service through recreational areas in the living environment (gardens etc.)	Final service that can be used directly	Recreation	Cultural
Possibility of identification through beautiful and characteristic landscapes (natural and cultural heritage)	Final service that can be used di-rectly	Well-being	Cultural
Local microclimate regulation performance through ecosystems	Final service that can be used directly	Well-being	Regulatory
A healthy air quality for humans	Natural / healthy habitat	Prevention	Regulatory
Silence	Natural / healthy living space	Prevention	Regulatory
A level of non-ionizing radiation that is compatible with human health	Natural / healthy living space	Prevention	Regulatory
Protection against avalanches, rockfalls and debris flow on steep slopes	Final service that can be used directly	Protection of people, animals and property	Regulatory
Protection through areas that are flooded or that can retain water	Final service that can be used directly	Protection of people, animals and property	Regulatory
Storage of CO_2*	Intermediate ecosystem service	Protection of people, animals and property	Regulatory
Existence of natural diversity at the level of species, genes, ecosystems and landscapes	Final service that can be used directly	Existence of natural diversity (in addition to the importance for all services)	Cultural
Natural supply of drinking and industrial water from usable groundwater and surface water	Final service that can be used directly	Water supply	Supply
Natural range of production support services: pollination and pest control	Ecosystem service as an input factor	Contribution to agriculture and forestry / Food industry	Regulatory
Fertile soil for agricultural and forestry use	Ecosystem service as an input factor	Contribution to agriculture and forestry / Food industry	Basic
Forage plants and organic fertilisers for agricultural use	Ecosystem service as an input factor	Contribution to agriculture and Food industry	Supply
Wood growth for forestry use	Ecosystem service as an input factor	Contribution to forestry	Supply
Wild animals and fish for commercial use	Ecosystem service as an input factor	Contribution to fishery and hunting	Supply
Offer of valuable natural and cultural landscapes for commercial use in tourism	Ecosystem service as an input factor	Contribution to tourism	Supply
Renewable energies: hydropower, wind power, biomass, solar energy and geothermal energy	Ecosystem service as an input factor	Contribution to the energy industry	Supply
Natural production support performance: cooling performance	Ecosystem service as an input factor	Cooling for different industries	Regulatory
Genetic resources and biochemical agents	Ecosystem service as an input factor	Contribution to the pharmaceutical industry, agriculture and others	Supply
Production support service: mining or storage of residues	Ecosystem service as an input factor	Contribution to waste water and waste disposal	Regulatory

Tab. 1: List of final ecosystem services[4].

*Exception, because actually an intermediate service, but benefits in the far future. Livelihood of future generations depends on it.

the lack of high-growing trees above the tree line. The further challenge is to check existing, identifiable ecosystem services as shown in Table 1 with the compatibility to golf course areas. Parameters must also be defined in order to make them measurable, in order to create the conditions for a subsequent evaluation of the ecosystem services on golf courses in Germany.

Authors:

Jan Rosenbusch,
Martin Thieme-Hack and
Wolfgang Praemassing,
Faculty of Agricultural Sciences and
Landscape Architecture at
University of Applied Sciences
Osnabrueck (Germany).

Increasing pollinator habitat through flowering lawns

Breece, C., A. Kowalewski, R. Sagili, E. Braithwaite and A. Cain

Introduction

Concerned citizens often express a desire to help pollinator populations and ask what they can do for bees in their communities. An easy and effective venture for citizens and managers of urban landscapes is to increase flowering plants in their landscapes, particularly those with high pollen and nectar content. Lawns in residential areas and corporate landscapes are often devoid of flowering plants, and provide little to no benefit to pollinators. However, alternative lawns have been gaining popularity[1], and recent research has explored the inclusion of flowering plants for pollinators in the lawns, or bee lawns[2,3]. The increasing interest in establishing pollinator habitat within home lawns, coupled with the environmental service provided by increased pollinator populations, presents a strong need for research and data pertaining to pollinator habitat in the home lawn. The objectives of this research were to identify flowering plants that establish and persist in a lawn, and provide resources for pollinator attraction in the Pacific Northwest.

Materials and Methods

On September 14, 2016, we established a field research trial at the Oregon State University Oak Creek Center for Urban Horticulture in Corvallis, Oregon, USA. Experimental design was a randomized complete block with three replications. The six seed mixtures included in this study were 1) perennial ryegrass, 2) Fleur de Lawn (commercially available mix), 3) bee lawn mixture I, 4) bee lawn mixture II, 5) flowering ground cover mixture and 6) bee meadow mixture (Table 1). Beginning in the spring of 2017, the perennial ryegrass, Fleur de Lawn, bee lawn mixture I, bee lawn mixture II, and flowering ground cover mixture were mowed weekly at a height of 7.62 cm, while the bee meadow mixture was not mowed. All plots were irrigated at a rate of 0.64 cm, three times per week. We surveyed each plot for plant diversity in 30 cm x 30 cm sub-plots (September 2017 and 2018) and counted insect pollinators in 1-minute intervals (September 2017).

	2018 percent plant cover (0-100%)Ś						
Seed Mixture[¥]	*Lolium perenne*	*Trifolium*	*Achillea*	*Bellis*	*Alyssum*	*Chamaemelum*	weeds
Fleur de Lawn	58.3	30.6	0.9	0.0	0.0	0.0	10.2
Bee lawn mix I	47.2	49.1	0.0	0.0	0.0	0.9	2.8
Bee lawn mix II	48.1	50.0	0.0	0.0	0.9	0.0	0.9
perennial ryegrass	73.1	17.6	0.9	0.0	0.9	0.0	7.4
flowering ground cover mix	25.9	66.7	0.0	0.0	2.8	0.0	4.6
Bee meadow mixture (not mowed)	*Rudbekia* (72.7%), *Gaillardia* (12.1%), *Coreopsis* (6.1%), *Lupinus* (6.1%), *Borago* (3.0%)						

[¥]Mixture composition (% by weight), seeding rate:

Fleur de Lawn: *Lolium perenne* (perennial ryegrass) (39%), *Festuca trachyphylla* (hard fescue) (20%), *Festuca ovina* (sheep fescue) (20%), flower mixture including *Trifolium fragiferum* (strawberry clover), *Trifolium repens* var. *pirouette* (microclover), *Bellis* (English daisy), *Achillea* (yarrow), *Alyssum*, and *Nemophila* (baby blue eyes) (19%), 4.8 grams per m^2.

Experimental bee lawn mixture I: perennial ryegrass (67.9%), *Trifolium repens* (Dutch white clover) (13.8%), microclover (13.8%), baby blue eyes (0.9%), *Phacelia* (1.8%), and *Chamaemelum* (roman chamomile) (1.8%), 17.9 grams per m^2.

Experimental bee lawn mixture II: perennial ryegrass (69.7%), Dutch white clover(14.2%), microclover (14.2%), *Cerasitum* (0.6%), yarrow (0.8%), and *Thymus serpyllum* (creeping thyme) (0.6%), 17.4 grams per m^2.

Perennial ryegrass: perennial ryegrass (100%), 48 grams per m^2.

Flowering ground cover mixture: Dutch white clover (44.5%), microclover (44.5%), *Ajuga* (1.3%), *Echium* (5.8%), *Cerasitum* (1.9%), and creeping thyme (1.9%), 5.6 grams per m^2.

Bee meadow mixture (not mowed): *Helianthus* (50%), *Rudbekia* (12%), *Gaillardia* (11%), *Eschscholzia californica* (California poppy) (9.3%), *Coreopsis* (6.1%), *Lupinus* (6.1%), *Borago* (7.0%), *Phacelia* (7.0%), 10.7 grams per m^2.

Percent plant cover was collected on September 14, 2018, two years after planting.

Tab. 1: Percent plant cover (0-100%) observed within the five seed mixtures that were mowed weekly at 7.62 cm and one mixture that was not mowed at the Oak Creek Center for Urban Horticulture in Corvallis, OR, plots were established on September 14, 2016.

Results and Discussion

The bee meadow mixture attracted the largest number of pollinators, followed by the flowering ground cover mixture (Table 2). Pollinators were recorded within the bee lawn mixture II plots, but these values were not significantly different from the perennial ryegrass (Lolium perenne), Fleur de Lawn and bee lawn mixture II plots, which did not attract any pollinators at this time. Findings from this research also determined that perennial ryegrass was prohibitively aggressive and prevented successful establishment of many other plants (Table 1). Trifolium sp. (clover) was also aggressive and outcompeted other flowering plants. We found that careful balancing of the quantities of perennial ryegrass, clover seed and other flowers is essential to a successful, diverse, flowering lawn. When trying to incorporate flowering plants from seed into existing lawns dominated by turfgrass and clover, de-thatching was a more successful seedbed preparation method in spring than in the fall.

Seed mixture[¥]	2017 pollinator visits[±]	
Fleur de Lawn	0.0	b[¥]
bee lawn mix I	0.0	b
bee lawn mix II	1.2	b
perennial ryegrass	0.0	b
flowering ground cover mix	3.0	ab
bee meadow mixture	5.3	a

[±]Pollinators observed within a 30 cm x 30 cm sub-plot over a 1 minute intervals on September 15, 2017, one year after planting.

[¥]Means followed by the same letter are not statistically different according to Fisher's least protected significant difference test at P≤ 0.05.

Tab. 2: Mean pollinator visits observed within the five seed mixtures that were mowed weekly at 7.62 cm and one mixture that was not mowed at the Oak Creek Center for Urban Horticulture in Corvallis, OR, plots were established on September 14, 2016.

The bee meadow, or un-mowed flowering plants established as a lawn alternative, substantially increased pollinator populations. Rudbekia, Gaillardia, Coreopsis, Lupinus and Borago were some of the more dominate species in our experimental bee meadow. Rudbekia become the dominate plant in these environmental conditions out competing the other species.

Findings from this research provide homeowners with alternatives to traditional home lawns and increase pollinator habitat. These alternatives include a variety of mowable ground cover mixtures with and without turfgrass, and flowering meadows, which could be established in place of lawns to substantially increase pollinator populations within the landscape.

Authors:

Carolyn Breece, Alec Kowalewski, Ramesh Sagili, Emily Braithwaite and Alyssa Cain
Department of Horticulture, Oregon State University, Corvallis, OR, USA.

[1] RAMER, J., K.C. NELSON, M. SPIVAK, E. WAKINS, J. WOFIN and M. PULSCHER, 2019: Exploring park visitor perceptions of 'flowering bee lawns' in neighborhood parks in Minneapolis, MN, US. Landscape and Urban Planning. 189:117-128.

[2] LANE, I., E. WATKINS and M. SPIVAK, 2019: Turfgrass Species Affect the Establishment and Bloom of Kura Clover (*Trifolium ambiguum*) in Lawns. HortScience. 54:824-828.

[3] LANE, I., J. WOLFIN, E. WATKINS and M. SPIVAK, 2019: Testing the Establishment of Eight Forbs in Mowed Lawns of Hard Fescue (*Festuca brevipila*) for Use in Pollinator Conservation. HortScience. 54:2150-2155.

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