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ETS

Special Edition

"Balancing turfgrass performance and sustainability"

Reviewed paper presented at the 4th ETS Conference 2014

Osnabrueck, Germany
6th to 9th July 2014

Hochschule Osnabrück
University of Applied Sciences

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Content

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Preface

The European Turfgrass Society (ETS) was established in 2007 aiming to provide a common ground and forum for everybody that is involved in the turfgrass industry such as researchers, companies, greenkeepers and others. ETS has achieved its goals through the organization of conferences and field days. So far ETS has successfully organized conferences in Pisa, Italy (2008), Angers, France (2010) and Kristiansand, Norway (2012) and field days in Valencia, Spain (2009); Ghent, Belgium (2011), Monte Carlo (2013) and a regional field day in San Michele all'Adige – Trento, Italy (2012).

In the recent years, European turfgrass industry has experienced unforeseen difficulties due to the worldwide economic recession that resulted in peoples' reduced quality of life narrowing their interest only to the basic human needs, namely food and clothing. Under such a narrow spectrum of thinking, sectors of ornamental and functional horticulture including turfgrass industry have shrunk.

Under these circumstances ETS networking has been proven to be a valuable tool to overcome the hurdles with collectively coordinated actions. These ETS efforts have been taking into account the contemporary needs of turfgrass industry aiming to the sustainable use of natural resources, the environmental protection and considering the perception of various stakeholders.

All the above are distilled into the main theme of the 4th ETS Conference to be held in Osnabrueck, Germany "Balancing turfgrass performance and sustainability". In Conference, research and professional experience will merge and exchange valuable and novel information aiming to promote turfgrass management and science under a collaborative and sustainable manner taking into account the current economical restrains. This knowledge and experience will be disseminated in the most efficient manner toward the turfgrass industry through more than 70 oral and poster presentations to the conference participants. In addition, all presentations will be available worldwide through their publication in the scientific journals European Journal of Horticulture Science and European Journal of Turfgrass Science.

These accomplishments are the result of hard work and great organizational skills that are performed by the Organizing Committee of the Conference at the University of Applied Science Osnabrueck. My sincere gratitude goes to all members of the Organizing Committee for realizing this 4th ETS Conference in such a short time and in particular to the convener Prof. Martin Thieme-Hack and his collaborator Dr. Klaus Mueller-Beck, President of the German Turf Society (Deutsche Rasengesellschaft e.V. DRG).

All these efforts would be impossible to accomplish without the precious input of ETS Board members. I would like to thank them all for their volunteered work and valuable input in the effort to sustain and grow ETS influence and networking throughout the European turfgrass industry during these two past years.

This volume contains extended abstracts, reviewed and presented in oral or poster form at the 4th European Turfgrass Society Conference. In addition a smaller part of full paper will be published in "European Journal of Horticulture Science".

All submitted contributions have undergone a thorough double blind peer review process by at least two independed reviewers of the scientific committee and an additional review from the Editorial Committee. The European Turfgrass Society acknowledges and appreciates the contribution of Authors, Reviewers and Editors which has been invaluable to the improvement of the quality of this publication.

Panayiotis A. Nektarios
The European Turfgrass Society President

Salute

Turfgrass research in Germany in recent years has not played such a significant role as in other countries represented by the conference participants. Even the “Rasen-Fachstelle“ at the University of Hohenheim suspended operations last year. The economic importance of functioning turfgrass research, according to Humboldt’s educational ideal, in conjunction with a turfgrass apprenticeship, whether for golf, sport or landscape is well known to the leaders of the European Turfgrass Society. We are hoping that this conference can give the field of turfgrass research and training in Germany new impetus.

The University of Applied Sciences, Osnabrueck, Faculty of Agricultural Sciences and Landscape Architecture is honored to be able to host, this, the 4th ETS conference in 2014. Our gratitude goes to the board of the ETS for this decision. But thanks must also be given to the organizing committee, in particular the President of the German Turfgrass Society, Dr. Klaus Müller-Beck, the many active referees of the two magazines European Journal of Horticulture Science and European Journal of Turfgrass Science (EJTS), especially chief editor Alessandra Zuin, the conference team and last but not least the sponsors.

May the conference be memorable for all participants.

Martin Thieme-Hack
Convener 4th ETS Conference 2014

Address of Welcome

The German Turfgrass Society (DRG) is delighted to welcome the participants of the 4th ETS Conference 2014 in Osnabrueck.

It is a pleasure to host the honored researchers and turfgrass specialist in Germany. In cooperation with the colleagues of the University of Applied Science Osnabrueck we have prepared and organized a conference to discuss and exchange the latest results on turfgrass research throughout Europe, the USA and Canada. The oral presentations and the poster sessions offer the opportunity to learn about the latest trends and to see what has been developed in different countries. We certainly hope that the ETS Conference releases a pulse for new turfgrass research activities in our country.

We are happy to share with you some impressions of our work on the university campus and to show you a few selected turfgrass projects with a breeding station, a golf course and a soccer pitch in the Bundesliga during our turf tour.

All submitted and reviewed 2-page paper are published in this Special Edition of our magazine “European Journal of Turfgrass Science”. This gives you a chance to study them in detail and to get into contact with the authors. Sustainability means In the spirit of the ETS to consider turfgrass knowledge and application in the broadest sense, including its use in sport and leisure, its role in improving urban quality and its importance in the mitigation of environmental effects.

We wish us a successful conference true to the motto: “Balancing turfgrass performance and sustainability”

The German Turfgrass Society is deeply grateful for the support by the patrons and sponsors to realize the 4th ETS Conference 2014 in Osnabrueck.

Welcome in Germany, July 2014

Klaus Mueller-Beck
President German Turfgrass Society

Content

Scientific Paper

Practical Paper

4th EUROPEAN TURFGRASS SOCIETY CONFERENCE

“Balancing turfgrass performance and sustainability”

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A special thank you to the referees of this 4th ETS Conference 2014 in Osnabrueck Germany for the time and attention devoted to the careful revision of the paper published in this special edition of the European Journal of Turfgrass Science

EDITORIAL BOARD

Precious water for a healthy environment and a permanent turf – a conflict?

Eid, U.

„Water is Life" is the motto of the water decade, which will end next year. Although about 71% our planet's surface is water-covered, only about 3% of all earth's water is fresh water. Out of this, most (more than 68%) is stored in glaciers, a smaller but still significant portion (30%) is stored underground, as soil moisture and in aquifers, and only about 1% is easily accessible in the form of surface water.

Water is unevenly distributed on our planet and availability varies depending on rainfall and groundwater resources but also due to factors affecting physical and economic accessibility, such as the technical and financial capabilities of water users. Population growth, pollution and waste, inefficient water use in agriculture (as by far the largest consumer of water), urbanization and climate change are some of the key factors contributing to a situation where especially in water-scarce countries lack of fresh water poses a threat to human and animal life and the environment. Although we are almost at the end of the UN-Water Decade, there are still around two billion people who have no access to safe drinking water and over 2.5 billion who do not have proper toilets, let alone are connected to sewage systems. 90% of municipal wastewater and 70% of industrial wastewater in developing countries go untreated into nature and contaminate not only important ecosystems but also low-income residential areas such as slums in megacities. Each day, 2,000 children under the age of five die from diarrheal diseases and of these some 1,800 deaths are linked to inadequate water, sanitation and hygiene. This is despite the fact that since 2010, access to safe drinking water and sanitation has been recognized as a human right under international law.

An improving standard of living is becoming an increasingly important factor for growing water consumption, also in water-scarce areas. For example, increasing meat consumption (the production of one kilogram of beef requires 15,400 liters of water) and more people owning a car (the production of a car swallows 150,000 liters of water) put pressure on water resources. Where fresh water is scarce, water-intensive recreational activities or tourism more generally can contribute to local and regional water shortage respectively.

A look on the world map designed according to the freshwater distribution based on the so called Falkenmark indicator (freshwater availability in m^3 per capita per year) shows:

- much of northern Africa and the Arabian Peninsula suffer from water scarcity (< 1,000 m^3/c/y)
- East Africa, southern Africa, the entire Indian subcontinent and parts of Eastern Europe are under water stress (< 1,700 m^3/c/y), and
- Central Europe, parts of Central and West Africa, Central Asia and China are vulnerable to lack of fresh water availability (< 2,500 m^3/p/y)

However, these general regional figures obscure the fact that even in some fresh water-rich countries such as the United States of America with an average fresh water availability of 6,000 m^3 per capita per year, individual regions have very little fresh water. This is, for example, the case in California, Nevada, and the Middle West.

Despite the fact that there are many people who claim that water is a local good, there are important voices that rightfully qualify this view, pointing to the global trade in virtual water and tourism. Regarding the former, water use in Germany is a good example: Whereas the direct consumption of drinking water from the water tap, with around 120 liters per capita per day, is moderate. Adding virtual water – of which a large proportion is imported, for example, through fruits, vegetables and textiles, partly from water-poor countries – per capita consumption per day rises to over 5,000 liters. With a population of 80 million, Germany's external water footprint is therefore immense.

Tourism has a similar effect (in this case not export of virtual water but imported water use) and is therefore another vehicle through which water acquires a global dimension. Many tourists from industrialized water-rich – 'bad weather' – countries prefer to spend their holidays abroad on sunny beaches, whose hinterland is often barren and arid. The same is true for golf tourists, many of whom like to try new courses in the shade of palm trees in the United Arab Emirates (UAE), Qatar, Abu Dhabi or Dubai, one of the water-poorest countries in the world. Now one might say that these countries have enough resources to generate fresh-water through desalination. But this ignores the fact that this comes at a huge cost in terms of – often still fossil – energy use. In fact, the Arab peninsula is facing huge challenges in terms of sustainable water resources management. Even such exotic places and at the same time fragile ecosystem like oases in the Sahara woo golfers, because for countries such as Egypt, Morocco and Tunisia, exclusive tourism has become an important economic factor. The Tunisian desert town of Tozeur has an 18-hole golf course despite the fact that fossil ground water stocks are already overexploited and the water table is falling, resulting in a situation where deep wells and high-performance, energy-intensive motor pumps are needed to extract water from up to 3,000 meters depth. This very much hints at a miscalculation of real costs, where benefits are privatized but costs are externalized. A problem which might also explain why Las Vegas, with an annual rainfall of 114,3 mm, the driest city in the United States, has a total of 61 golf courses.

Golf is a very good example for the key aspects that need to be considered regarding water: where and how much of it is used and how does the amount used relates to other water uses and available water resources in the affected region.

If the water consumption for a 18-hole course in Central Europe is at about 35,000 m^3 per year, a golf course in Dubai consumes 3,500 m^3 every day. With growing problems concerning fresh water availability the solution pressure has increased as well. All over the world, people are trying to make golf courses more environmentally friendly and resource- efficient. Today, in Las Vegas every golf course has to operate under a mandatory and strictly regulated water budget. The German Golf Association has established a water working group that is working on a method to determine the precise water need, avoiding over-irrigation. Architects and engineers have started to improve the design of irrigation and drainage technologies to increase water efficiency. The selection of the proper type of grass can reduce water consumption by as much as 50%. In the United Arab Emirates all golf courses have changed to paspalum-grass, which is resistant to salty water.

However, the fundamental question remains: Are there not certain environmental conditions where constructing and operating a golf course as such is unreasonable, considering total local fresh water availability and other – priority – uses? In the end, how to answer this question depends on political choices and prioritization. In any case, it is welcomed to see the growing awareness of the problem.

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Standardization work for golf and sports grounds in Germany – check, supply, design and build

Thieme-Hack, M.

Abstract

Since the early 1970s, a branched and entangled mesh of regulations has been established around turfgrass. In addition to the legal requirements, the German Institute for Standardization (DIN) and the Research Society Landscape Development and Landscape Construction (FLL) are leaders in standardization work. These standards and regulations give instructions about testing, the supply and construction through to the care and maintenance of turfgrass. Additionally, far-reaching guidance to precisely defined contractual conditions are made available. Almost everything to assist practitioners in their daily work.

1 Introduction

Standards are primarily intended to facilitate the movement of goods, businesses to business and businesses to consumers, ensuring a minimum quality and bringing about a reasonable balance of interests between the parties. Therefore, standardization work is often laborious and regularly shaped by the interests of stakeholders. Standards and regulations in the Federal Republic of Germany are not only developed by the DIN, the German Institute for Standardization, but also from other institutions who are willing to lead a consensus brought about to serve the profession.

Formal standardization work in Germany is characterized by two main areas:

1. **German Construction Contract Procedures**; forms the contractual basis for almost all contracts for work and services which apply to the construction of golf courses and sports facilities.
2. **European Union Regulations**; in particular the so-called “construction products law”.

Over time, it has been established that the standards and regulations should not be overloaded with content. The key standards institutions and regulators can therefore be distinguished according to the standards function:

- Test standards:
- How can a performance or material be tested?
- Construction products, conditions of sale and delivery:
- How should materials and components (plants, seeds) be procured?
- Quality protection, quality control: How can the quality of materials, components or construction work be ensured through external monitoring?

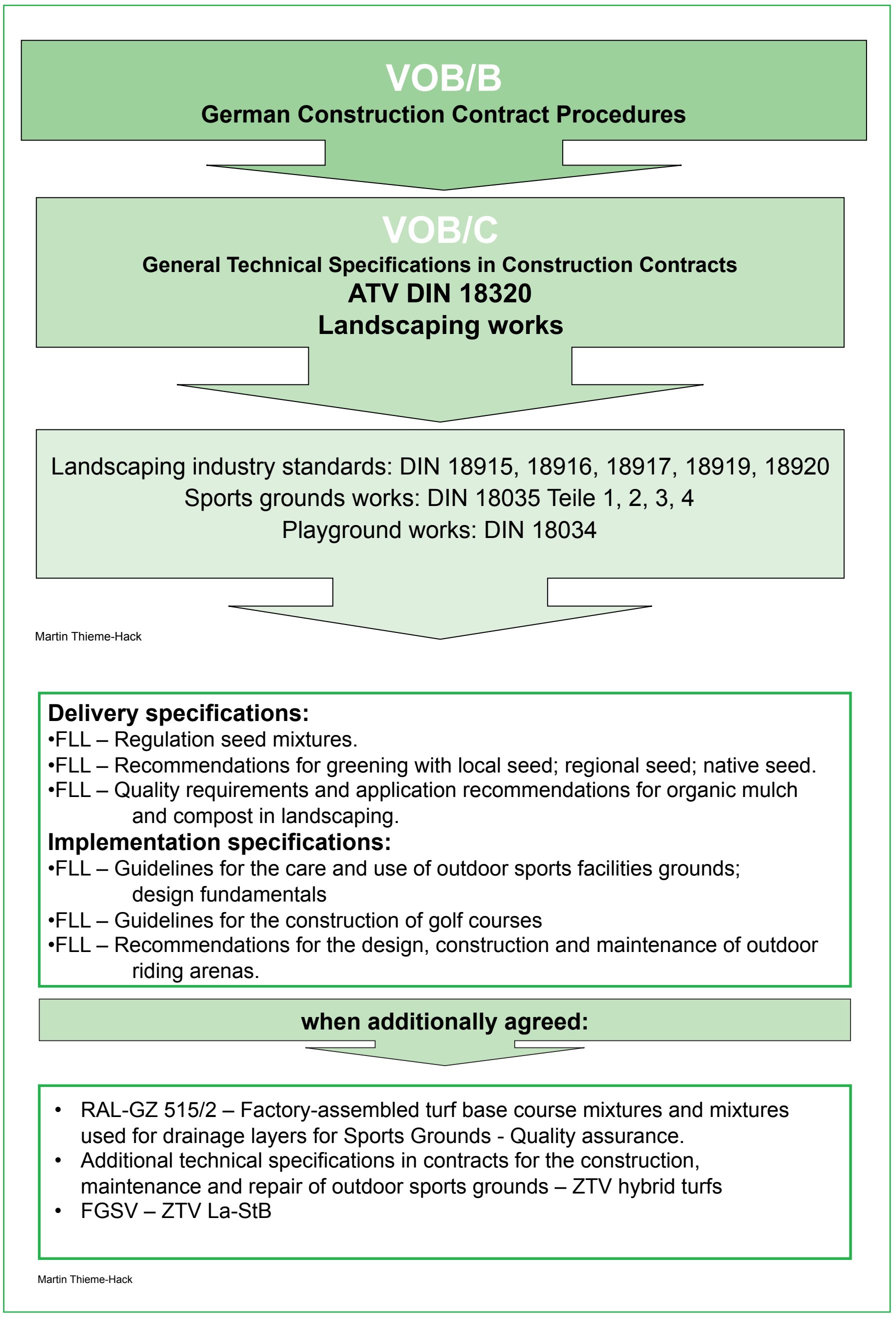

Fig. 1: Standards cascade in golf course, landscaping and sports ground construction.

– Fundamental and planning standards, design standards: How is the performance to be designed, implemented and manufactured?

Standards and regulations are intended to serve the principle of universality. On the one hand, standards can only reflect a standard situation and the user must decide in each case on the application of a standard. On the other hand, they are also a medium in which stakeholders can promote their interests by introducing certain regulations or by excluding competition from the market. The Federal Administrative Court formulated a guiding principle in a judgment as follows:

"It is true that, on the one hand the DIN standards' expertise and responsibility for the general welfare cannot be denied. On the other hand, one should be aware that these are also agreements within certain circles, commissioned to have an influence over market events" (source: Federal Administrative Court, Case No. 4C 33-35/83 in: NJW 87, 2888)

Therefore, standards and regulations must always be critically examined by the user.

2 Standards cascade of the Construction Contract Procedures

According to the principle behind the definitions of contractual obligations as laid out in § 631 German Civil Code (BGB), the contractor has to provide the performance, free of defects, by the time of official acceptance. For this, the performance must achieve the "agreed upon condition" and meet the "generally recognized codes of practice".

The German Committee for Construction Tendering and Contract Procedures (DVA) introduced the term "agreed upon condition" in 1927. The term is defined by the construction and contract procedures through a "cascade" of standards and regulations (Figure 1).

With that, the German Construction Contract Procedures VOB/B (DIN 1961) are agreed and, as a consequence, a number of regulations referenced therein. Within the upper level of the General Technical Specifications in Construction Contracts (ATV) are standards which are particularly relevant for the construction and maintenance of turfgrass:

– ATV DIN 18299 General rules applying to all types of construction work

– ATV DIN 18300 Earthwork

– ATV DIN 18306 Underground drainage

– ATV DIN 18308 Land drainage and infiltration management works

– ATV DIN 18320 Landscape Work

All further relevant standards and regulations will be discussed below.

3 Free movement of goods within the European Union

The Federal Republic of Germany has committed itself to ensuring the free movement of goods within the European Union. It is also paramount that national regulations pertaining to building materials should not be in contradiction with corresponding European regulations. Germany has enshrined this in the *"Law on the marketing and free movement of construction products for the implementation of Directive 89/106/EEC from the Council of 21 December 1988 for the harmonization of laws, regulations and administrative provisions for construction products within the member states and other legislative acts of the European Union (EU construction)"*.

Differing national regulations on construction products hinder the free movement of goods and are considered market foreclosure instruments for the protection of national interests. Therefore, the European Commission is required to examine possible breaches and, where necessary, take action against such contravening regulations or standards.

Additionally, there are also laws and regulations that have not been left to

species	category B = base seed C = cert. seed	minimum germination capacity (in mass-%)	technical minimum purity (in % grains)	alien species content (in mass-%)	max. moisture content (in%)
Agrostis capillaris – common bent, browntop	B	75%	90%	0,3%	14%
	C	75%	90%	2,0%	
Agrostis stolonifera – creeping bentgrass, redtop	B	80%	90%	0,3%	
	C	80%	90%	2,0%	
Festuca arundinacea – tall fescue	B	80%	95%	0,3%	
	C	80%	95%	1,5%	
Festuca ovina – sheep fescue	B	75%	85%	0,3%	
	C	75%	85%	2,0%	
Festuca rubra – creeping red fescue	B	75%	90%	0,3%	
	C	75%	90%	1,5%	
Lolium perenne – perennial ryegrass	B	80%	96%	0,3%	
	C	80%	96%	1,5%	
Poa pratensis – Kentucky bluegrass	B	75%	85%	0,3%	
	C	75%	85%	2,0%	
Poa supina – Supina bluegrass	B	75%	85%	0,3%	
	C	75%	85%	2,0%	
according to the Seed Marketing Act as of 24.07.2007 Additional requirements for permissible levels of alien species content of redroot pigweed, sorrel, wild oats, wild oats bastards, couch grass and dodder					

Tab. 1: Minimum seed requirements: Germination capacity, purity, alien species content und moisture according to the Seed Marketing Act.

type	use	characteristics[1]	maintenance requirements
ornamental grass	ornamental greening	dense carpet-like thatching from fine-leaved grasses, low resilience	high to very high
lawns	public greens, residential greening, private gardens etc.	medium resilience, resistant to dry periods	medium to high
sports turf	Sport and play areas, public lawns, parking lots	high resilience (all year)	medium to very high
landscape turf (extensive turf)	most extensively used and / or maintained areas in public and private green, in the countryside, in areas along transport routes, reclamation areas and similar areas rich in species	lawns with a large variation depending on the usage and location, e.g. erosion control, resistance to extreme locations, basis for the development of site-specific habitats, usually little or no load	low to medium in special cases very high
1 density and resilience to loading diminish with increasing shade.			

Tab. 2: Turfgrass types according to DIN 18917.

the standardization institute by the legislature, but have been found to be particularly needed.

4 Institutions doing regulatory work for turfgrass

The German Institute for Standardization (DIN) and the Research Society Landscape Development and Landscape Construction (FLL) work to develop guidelines for the area of turfgrass within the legal framework.

4.1 German Institute for Standardization (DIN)

The German Institute for Standardization (DIN), with over 30,000 standards involving around 26,000 in-house and external experts, with a budget of approximately 68 million Euros / year and over 300 employees, is the only nationally recognized standards organization. The State Treaty is from 1975.

The DIN has identified the following principles for its standardization work:

- Standards and standardization secures Germany's position as a leading economic nation.
- Standards and standardization as a strategic tool supports the success of the economy and society.
- Standards and standardization unburden the state rulemaking process.
- Standards and standardization promote technology convergence.

The title of a DIN standard shows its significance and area of application.

a) Fully consensus-based documents:

- DIN 12345: National Standard
- DIN EN 12345 German edition of a European Standard (EN)
- DIN EN ISO 12345 German edition of an International Standard (ISO)

b) Not fully consensus-based documents (DIN SPEC):

- DIN V 12345 DIN pre-standard
- DIN CWA 12345 (CEN / CENELEC Workshop Agreement)
- DIN 12345 PAS (Publicly Available Specification)

In contrast to the principles and rules of the DIN 820, all procedures that fall under the umbrella term DIN SPEC need not be initially published as draft versions. All documents under the umbrella term DIN SPEC are not part of the German standardization work because, among other things, the necessary "degree of consensus" is not necessarily reached. However, DIN SPEC is not necessarily in contravention with the requirements of the standards, whether national or European.

The DIN begins with a standardization project when "interested parties" see the need and existing regulations do not negate the standardization project.

4.2 Research Society Landscape Development and Landscape Construction (FLL)

The 50 FLL interdisciplinary working committees are assembled from 30 professional and trade associations – all members of the FLL. Thus, by constitution, the participation of all "green associations" is ensured. The committees are appointed by delegation from the member associations or experts from its more than 20,000 members.

The FLL issues different types of publications:

4.2.1 Contract documents: Reaching contractual agreement between the Principal and Agent:

- Technical Testing requirements (TP),
- Technical Specifications (TL),
- Additional Technical Terms and Conditions of Contract (ZTV).

4.2.2 Guidelines: Advice for planning, design, care and maintenance. These are intended to reflect the generally recognized codes of practice. The term "generally recognized codes of practice" means construction methods and designs, verified in theory, which are used by the vast majority of practitioners and have proved to be successful in practice.

4.2.3 Recommendations: Advice for planning, design, care and maintenance. These represent the current state-of-the-art techniques. They should be tried and tested in order to develop the generally recognized codes of practice. They are a precursor to the guidelines. The term "current state-of-the-art techniques" means contemporary technical possibilities which have not yet undergone full, long-term practical application.

4.2.4 Technical Reports: Advice for planning, design, care and maintenance. Specialist reports are intended to provide information to clients, planners, construction companies and other interested parties. They can be used as a guide and instructions for professional conduct.

4.2.5 Other informative publications.

5 Relevant turfgrass regulations

5.1 Testing requirements

As part of the implementation of projects, testing is distinguished accord-

RSM No.	name:	climate:	location:	resilience:	usage:	maintenance:	sowing amount:
3.1	new constructions	no limitations	no limitations	high, all year	sports grounds	medium to high	25 g/m^2
3.2	regeneration	no limitations	no limitations	high	regeneration of sports and playing fields	medium to high	30 g/m^2

mixture content in mass-%			
species		RSM No.	
		3.1	3.2
Lolium perenne			
	standard	25	60
	scope	20-30	50-80
	minimum	8	8
Lolium perenne			
	standard	15	25
	scope	10-20	20-30
	minimum	7	7
Poa pratensis			
	standard	25	15
	scope	15-35	0-20
	minimum	7	6
Poa pratensis			
	standard	20	
	scope	10-30	
	minimum	6	
Poa pratensis			
	standard	15	
	scope	10-20	
	minimum	6	

Tab. 3: Sports turf according to RSM 2014.

ing to when it is carried out and who should bear the costs:

- **Suitability tests:** These are tests to demonstrate the suitability of materials and building material mixtures used for the intended purpose in accordance with the requirements of the contract. Examination by the Contractor, or the supplier.
- **Self-monitoring tests:** These are tests, including incoming material inspections by the contractor, to determine whether the qualitative properties of building materials and building material mixtures conform to the contractual requirements.
- **Verification tests:** verification tests done by the client, in order to determine whether the qualitative properties of building materials and building material mixtures conform to the contractual requirements.

An overview of the applicable testing requirements is given below. The assignment to a category a), b) or c) and the lists themselves are not exhaustive. For example, tests for preliminary investigations can also be relevant in the assessment of the delivery and vice versa.

Preliminary investigations; tests to assess the site:

- DIN 18123, Soil, investigation and testing - Determination of grain-size distribution
- DIN 18128, Soil – Investigation and testing – Determination of ignition loss
- DIN 19682-7, Soil quality – Field tests – Part 7: Determination of infiltration rate by double ring infiltrometer

b) Tests for the supply of materials and components

- DIN 18121-1, Soil, investigation and testing – Water content – Part 1: Determination by drying in oven

c) Evaluation of the performance

- DIN EN 12231, Surfaces for sports areas – Method of test – Determination of ground cover of natural turf; German version EN 12231:2003, July 2003, DIN German Institute for Standardization, Berlin
- DIN EN 12232, Surfaces for sports areas – Determination of thatch depth of natural turf; German version EN 12232:2003, July 2003, DIN German Institute for Standardization, Berlin
- DIN EN 12233 Surfaces for sports areas – Determination of sward height of natural turf; German version EN 12233:2003July 2003, DIN German Institute for Standardization, Berlin
- DIN EN 12616, Surfaces for sports areas – Determination of water infiltration rate; German version EN 12616:2013
- DIN EN 13036-7, Road and airfield surface characteristics – Test methods – Part 7: Irregularity measurement of pavement courses: The straightedge test; German version EN 13036-7:2003
- DIN ISO 10390, Soil quality – Determination of pH (ISO 10390:2005)
- Association of German Agricultural Analytic and Research Institutes (VDLUFA), method books, Volume I – Soil, 1st partial delivery / groundwork, 1991 5)
- Association of German Agricultural Analytic and Research Institutes (VDLUFA), method books, Volume I – Soil, 2nd partial delivery, 1997 5)

In the area of testing standards, it has been impossible to reach a consensus for the testing of water permeability in turf base-course mixtures in the laboratory. A professional opinion advocates testing at a defined Proctor compaction level. The others reject this; because of the organic substances no reproducible Proctor compaction test results can be expected.

5.2 Delivery specifications

Statutory delivery specifications arise from the *German Seed Marketing Act (SaatG), the Regulation of the marketing of fertilizers, soil additives, growing media and plant growth additives (Fertilizer Act – DüMV) and the regulation on the utilization of bio-waste in agricultural, forestry and horticultural soils (Bio waste Act – BioAbfV)*.

According to the Seed Act, the following categories of seed can be distinguished:

- Basic seed
- Certified seed
- Commercial seed
- Auxiliary seed

Requirements of the seed according the Seed Marketing Act are exemplified in Table 1.

The DIN 18917 Vegetation technology in landscaping – Turf and seeding distinguishes turfgrass types according to Table 2.

Based on these types of turfgrass, the first regulated seed mixtures were developed in 1979. Today, the FLL issues an annual list, in which the regulation seed mixtures are described and grass varieties named. In 2014, the following mixtures are described:

RSM 1.1 ornamental grass

RSM 2.2 lawns –
dry locations (variants 1 and 2)

RSM 2.3 lawns –
playing fields (according to DIN 18917 resilient turf)

RSM 2.4 lawns – herb lawn

RSM 3.1 sports turf –
new installation (according to DIN 18917 resilient turf)

RSM 3.2 sports turf –
Regeneration (according to DIN 18917 resilient turf)

RSM 4.1 golf turf –
Green (variants 1 to 3)

RSM 4.3 golf turf – Tee

RSM 4.4 golf turf –
Fairway (variants 1 to 4)

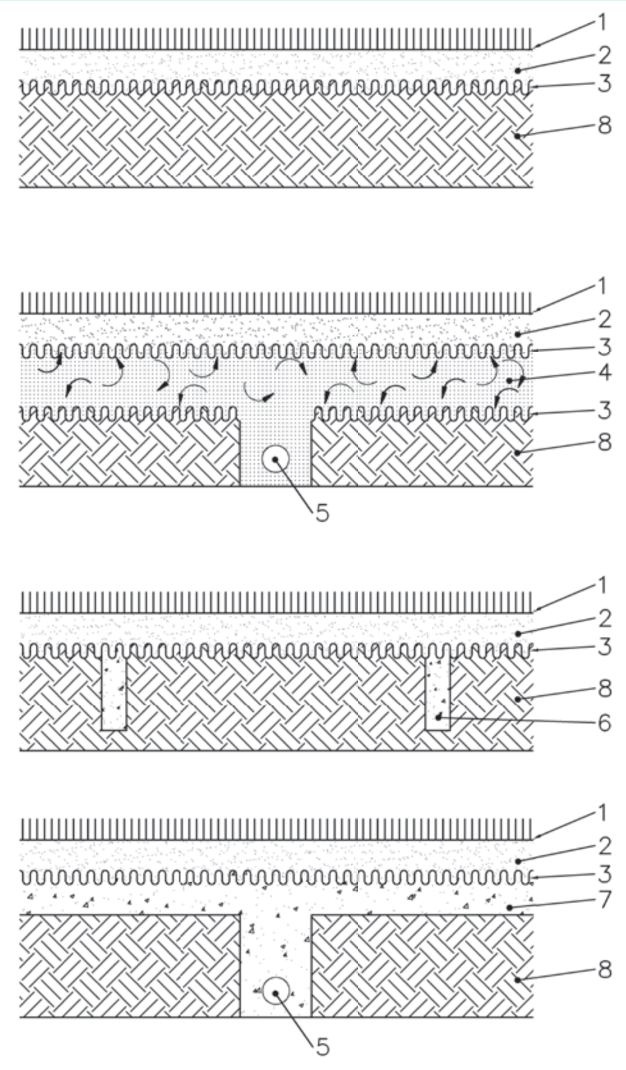

Fig. 2: Examples of construction according to DIN 18035-4 Key: 1 turf, 2 turf base course, 3 interlocking, 4 improved subsoil, 5 drainage line with drain pipe, drainage Chanel 6, 7 drainage course, 8 subsoil

RSM 5.1 parking lot turf
(variants 1-2)

RSM 6.1 Extensive roof greening

RSM 7.1.1 Landscape turf –
Standard without herbs

RSM 7.1.2 Landscape turf –
Standard with herbs

RSM 7.2.1 Landscape turf –
dry location without herbs

RSM 7.2.2 Landscape turf –
dry location with herbs

RSM 7.3 Landscape turf –
wet locations

RSM 7.4 Landscape turf –
half-shade

RSM 8.1 Biotopes / species-rich extensive grassland (variants 1 to 4)

An example for the regulation seed mixtures is shown in Table 3.

Brand new, are the FLL – *Recommendations for greening with indigenous seed; regional seed; native seed.*

Indigenous, meaning seed compositions with grasses and herbs “from the region” with which the genetic and biological diversity of the respective location is to be maintained. This takes into consideration the requirements of the Nature Conservation Act according to which, non-native plants may only be introduced into the wild with permission from the relevant State Authority.

The FLL is currently preparing a regulation, which is to describe the technical specification of turfs.

Additional effective regulations in the field of golf course construction and sports facilities are to be found in *TL aggregates – Technical delivery specifications for aggregates used in road construction* from the FSGV Cologne, in which the particular properties of scaffold materials for the production of turf base course mixtures are defined.

5.3 Fundamental, planning and implementation specifications

The following regulations are relevant here:

properties	requirements	testing to
grain size distribution	0/1 mm to 0/22 mm	DIN EN 933-1
water permeability k*(1)	≥ 1 x 10^{-3} cm/s	DIN 18035-5
organic substance content	≥ 1 % und ≤ 3 %	DIN 18128 and additionally to DIN 18035-4
soil pH	between pH 5,5 und pH 7,5	DIN ISO 10390
resistance to freezing stress on the scaffold materials	category F4 according to TL Gestein-StB	DIN EN 1367-1
salt content	≤ 150 mg/100 g substrate	VDLUFA
plant tolerance	germination and development of the trial planting minimum level “gut”	VDLUFA

Tab. 4: Demands on the supply of base course materials for sports turfs (Source Thieme-Hack in: Teaching in 2013 performed in accordance with DIN 18035-4).

characteristics	requirements	testing to
minimum density	without drainage layer 80 mm with drainage layer 120 mm	—
water infiltration rate IC	≥ 60 mm/h	DIN EN 12616 method C and additionally DIN 18035-4
shearing resistance	> 12 kPa	DIN 18035-4
fall	must be compatible with the turf base course	leveling
height	tolerances from the given height ± 20 mm	leveling
flatness	maximum deviation at measuring points over 4 m ≤ 20 mm	DIN EN 13036-7

Tab. 5: Requirements for the turf base course for sports turfs (Source Thieme-Hack in: Teaching in 2013 performed in accordance with DIN 18035-4).

a) Landscaping

- DIN 18917 Vegetation technology in landscaping – Turf and seeding
- DIN 18918 Vegetation technology in landscaping – Biological methods of site stabilization – Stabilization by seeding and planting, stabilization by means of living plant material, dead material and building elements, combined construction methods
- DIN 18919 Vegetation technology in landscaping – Care of vegetation during development and maintenance in green areas

b) Sports grounds construction

- DIN 18035-1, Sports grounds – Part 1: Outdoor play and athletics areas, planning and dimensions
- DIN 18035-2, Sports grounds – Part 2: Irrigation
- DIN 18035-3:2006-09, Sports grounds – Part 3: Drainage
- DIN 18035-4, Sports grounds – Part 4: Sports turf areas
- Research Society Landscape Development and Landscape Construction: Guidelines for the care and use of outdoor sports facilities grounds; design fundamentals
- Research Society Landscape Development and Landscape Construction: Recommendations for the design, construction and maintenance of outdoor riding arenas.

c) Golf courses

- Research Society Landscape Development and Landscape Construction: Guidelines for the construction of golf courses

Further guidance is available from the Federal Institute of Sport Science (BISp), the International Association for Sports and Leisure Facilities (IAKS) and the German Football Association (DFB).

DIN 18035-4 provides possible design examples in the informative appendix. These examples are not exhaustive. In particular, the constituents of the construction are combined, e.g. the drainage channels and ground improvement.

An example of these construction methods for turfed sports fields is given in Figure 2 according to DIN 18035-4. The technical requirements are provided in excerpts in Tables 4 and 5.

Depending on the choice of construction design, the following elements may be implemented:

- building with drainage lines,
- drainage course,
- improved Building,
- subsoil improvement,
- drainage channels
- turf base course,
- compound interlocking,
- turfgrass through sowing or sods.

The choice of construction method or the construction of the turf playing field depends on the local conditions. These are in particular:

- water infiltration rate of the subsoil,
- rainfall,
- water table, strata water and leachate
- suitability of the existing soil,
- availability of scaffold materials,
- availability or willingness to provide irrigation water,
- scope of maintenance services.

Even industrial companies give themselves to regulations. One example is the regulations published under RAL German Institute for Quality Assurance and Certification, e.g. RAL -GZ 515/2 – *Factory-assembled turf base course mixtures and mixtures used for drainage layers for Sports Grounds* – Quality assurance of the quality community tennis courts and natural turf construction materials, Duisburg. Another example is additional technical specifications in contracts for the construction, maintenance and repair of hybrid turfgrass for outdoor sports grounds – ZTV hybrid turfgrass, which was published by a group of sports grounds companies to the assure customers about the defined qualities and transparent benefits of an increasingly popular construction method in Germany.

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Assessing cool-season turfgrass blends and mixtures under low maintenance

Park, B.S., W.A. Meyer, S.A. Bonos and J.A. Murphy

Introduction

There is increased interest in maintaining cool-season turfgrasses under limited N fertility, irrigation, and pesticide inputs for home lawns and other grounds. Seed mixtures are commonly recommended for the purpose of broadening the diversity and adaptation of the established turf; however, there is limited data available comparing the performance of seed mixtures. The objective of this trial was to evaluate the long-term performance of cool-season turfgrass blends and mixtures under minimal management inputs.

Materials and Methods

One-hundred-five (105) entries were seeded in September 2011 on a loam in North Brunswick, NJ, USA. Ninety-one of the entries consisted of blends and mixtures of hard fescue ('Beacon' and 'Firefly' *Festuca brevipila* R. Tracey), Chewings fescue ('Fairmont' and 'Intrigue II' *F. rubra* L. subsp. *fallax* [Thuill.] Nyman), strong creeping red fescue ('Celestial' and 'Wendy Jean' *F. rubra* L. subsp. *rubra*), tall fescue ('Bullseye', 'Faith', and 'Mustang 4' *F. arundinacea* Schreb.), perennial ryegrass ('Fiesta 4', 'Paragon GLR', and PPG-PR 164 *Lolium perenne* L.), 'Light' Kentucky bluegrass ('Bluenote' and A05-361 *Poa pratensis* L.), and "Dark" Kentucky bluegrass ('Midnight II' and 'Bewitched'). Each component of a seed blend or mixture was added in equivalent quantities based on seed count (e.g., 50:50%; 33.3:33.3:33.3%; 25:25:25:25%; etc.). These 91 entries were seeded at 2.3 seeds cm^{-2}. Fourteen retail seed blends and mixtures were also seeded using the seeding rate recommended on the package. Plot size was 1.5- x 1.8-m. All entries were replicated three times and arranged in a randomized complete block design.

The entire trial was fertilized with 24.4 kg ha^{-1} of N at the time of seeding; 18.5, 20.5, and 48.8 kg ha^{-1} in March, April, and August 2012, respectively; 37.6 and 45.9 kg ha^{-1} in March and August 2013, respectively. Nitrogen forms were ammonium, urea, and polymer coated urea. Calcitic lime was applied at 2,280 kg ha^{-1} in August 2012 based on a soil test recommendation. The trial was irrigated once in July 2012 and 2013 with 2.5 cm of water. A rotary mower was used no more than once per week during periods of active growth; a bench-setting of 7.6- and 6.4-cm was used during 2012 and 2013, respectively. Plots were not mowed during periods of drought stress.

Dimethyl tetrachloroterephthalate (DCPA) was applied on 4 April 2012 at 6.7 kg ha^{-1} to prevent summer annual weed encroachment during spring 2012. Fenoxaprop-p-ethyl [(+)-ethyl 2-[4-[(6-chloro-2-benzoxazolyl)oxy] phenoxy]propanoate] was applied 0.3 kg ha^{-1} on 2 Aug. 2013 for postemergence control of crabgrass (*Digitaria* spp.). Triclopyr (3,5,6-trichloro-2-pyridinyloxacetic acid, triethylamine salt) was applied at 0.8 kg ha^{-1} on 21 September 2011 and triclopyr and 2,4-Dichlorophenoxyacetic acid were applied at 1.1 and 0.5 kg ha^{-1}, respectively on 13 September 2013 for postemergence broadleaf weed control.

Plots were visually rated for establishment (26 October 2011) and turf quality monthly from April through October during 2012 and 2013. Weed encroachment was evaluated on 26 July 2012 and 26 July and 5 September 2013. The predominant weed in the trial in 2012 was yellow woodsorrel (*Oxalis stricta* L.). In 2013, observed weeds included yellow woodsorrel, crabgrass, white clover (*Trifolium repens* L.), and yellow nutsedge (*Cyperus esculentus* L.). Gray leaf spot disease (caused by *Pyricularia grisea* [Cooke] Sacc. [syn *P. oryzae* Cavara]) was observed in the trial in early fall 2012 and was rated on 2 October 2012. Red thread disease (caused by *Laetisaria fuciformis* [McAlpine] Burdsall [anamorph *Isaria fuciformis* Berk.]) was rated on 31 May and 24 June 2013. Summer patch disease (caused by *Magnaporthe poae* Landschoot & Jackson) developed during 2013 and was assessed on 28 August. All ratings used a 1 to 9 scale where 9 equaled the best turf characteristic and 5 represented a minimally acceptable level. Turfgrass quality data were averaged for 2012, 2013, and 2012-13. Data were subjected to analysis of variance and means were separated using Fisher's protected least significant difference (LSD) test at $p < 0.05$.

Results and Discussion

As expected, entries with the most rapid establishment were the blend and mixtures containing *L. perenne*. Entries with the poorest establishment were the two *P. pratensis* blends and three mixtures containing 50% *P. pratensis* mixed with *F. brevipila* and *F. rubra* L. subsp. *fallax*.

Botanical composition of plots was not quantified but it was visually apparent that mixed-species swards had developed from most seed mixtures containing *L. perenne*; the major exception was *L. perenne* dominating swards of the *P. pratensis* and *L. perenne* seed mixtures.

The blend and ten mixtures containing *F. brevipila* were among the 14 entries that had an average turf quality ≥ 5.0 during 2012. Entries with the poorest average turf quality during 2012 included the two *P. pratensis* blends, which was attributed to the very slow establishment rate of this species and exacerbated by the low rate of N fertilization of this trial.

Seventy-four blends and mixtures had the least weed encroachment on 12 July 2012. Fifty-nine of the entries had limited weed encroachment (rating ≥ 7.0) and 38 of these entries contained *L. perenne*. Ten mixtures exhibited less than acceptable weed encroachment (< 6.0); among these, *P. pratensis* was the most common component of nine mixtures.

Sixty-four entries exhibited the least susceptibility to gray leaf spot disease on 2 October 2012. The *L. perenne* blend and thirteen mixtures containing *L. perenne* were among those 64 entries with the least gray leaf spot. None of the retail mixtures containing *L. perenne* were among the entries with the least gray leaf spot susceptibility. In fact, of the 15 entries that had the

Species Composition of Seed Blend or Mixture†					Turf Establishment‡	Average Turf Quality§	Summer Patch¶
F. brevipila	*F. arundinacea*	*Lolium perenne*	*Poa pratensis* Light	*Poa pratensis* Dark	26 Oct. 2011	2012	28 Aug. 2013
% (by weight)					1 to 9 rating scale		
32.4		67.6			8.7	5.3	7.3
29.0		60.6	10.4		7.7	4.8	6.3
29.2		60.8		10.0	7.3	4.0	7.3
27.1	72.9				6.7	4.0	7.3
17.3	46.6	36.1			7.7	4.3	8.0
16.3	43.9	34.0	5.8		7.0	4.3	7.7
16.3	44.0	34.1		5.6	7.0	3.8	5.7
73.6			26.4		2.3	5.6	2.3
74.4				26.6	2.3	5.4	2.3
100.0					3.3	5.2	1.3
	88.3		11.7		5.7	3.9	9.0
	88.7			11.3	5.7	3.6	9.0
24.7	66.5		8.8		5.7	3.8	5.7
24.8	66.7			8.5	6.0	4.2	6.3
	56.4	43.6			8.3	4.2	9.0
	52.4	40.6	7.0		6.7	3.9	8.3
	52.6	40.7		6.7	7.3	5.2	8.3
	100.0				6.7	3.6	9.0
		100.0			7.7	4.5	9.0
		85.3	14.7		7.3	4.7	8.7
		85.9		14.1	7.7	4.6	8.7
			100.0		1.0	1.6	---
				100.0	1.0	1.4	---
LSD (0.05)					1.5	1.1	1.7

† 'Beacon' and 'Firefly' *Festuca brevipila*; 'Bullseye', 'Faith', and 'Mustang 4' *F. arundinacea*'; 'Fiesta 4', 'Paragon GLR', and PPG-PR 164 *Lolium perenne*; 'Bluenote' and A05-361 *Poa pratensis* (Light); 'Midnight II' and 'Bewitched' *Poa pratensis* (Dark)

‡ 9 = best establishment

§ Average of seven observations during 2012 and 2013 (Apr., May, June, July, Aug., Sept., and Oct.); 9 = best turf quality; plot integrity of *Poa pratensis* blends (Light and Dark) severely declined in 2013 and turf quality could not be accurately evaluated.

¶ 9 = least disease; plot integrity of *Poa pratensis* blends (Light and Dark) severely declined in 2013 and summer patch susceptibility could not be accurately evaluated.

Tab. 1: Turfgrass establishment, average turfgrass quality, and summer patch disease susceptibility of selected cool-season turfgrass blends and mixtures in a low maintenance trial seeded September 2011 in North Brunswick, New Jersey, USA.

greatest susceptibility to gray leaf spot, nine were retail mixtures containing *L. perenne*.

The average turf quality scores during 2012 and 2013 indicated that many of the better performing mixtures contained *F. brevipila* and *L. perenne*. However, the development of summer patch disease in 2013 resulted in a dramatic decline in the turf quality of *F. brevipila* and mixtures of *F. brevipila* and *P. pratensis* during late summer. Interestingly, the performance of the *F. brevipila* and *L. perenne* mixture did not suffer from summer patch damage suggesting that mixing with *L. perenne* may provide protection to *F. brevipila* from this disease. Similarly, the inclusion of *F. arundinacea* with summer patch susceptible species such as *F. brevipila*, *F. rubra* L. subsp. fallax, and *P. pratensis* has also limited the damage caused by summer patch disease. The performance *F. arundinacea* during 2013 improved significantly compared to 2012 suggesting that establishment of this species was slow and may be due to the relatively low N fertilization used in this trial. By the end of 2013, the best turf performance was observed in mixtures that contained *L. perenne* and/or *F. arundinacea*.

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'AU Victory': A new bentgrass cultivar from Auburn University

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Introduction

Creeping bentgrass has long been used as a putting green grass because it offers superior playability, dense turf and a dark green color. It is the only *Agrostis* species suitable for the southeastern United States but suffers in the prolonged heat and humidity of summer, and thin and poor stands are a result. While cultural practices such as fans and syringing help (GUERTAL et al., 2005) there has been a definitive shift to ultradwarf bermudagrass (*Cynodon dactylon* (L.) Pers. *x Cynodon transvaalensis* Burtt-Davy) cultivars. However, many golfers and turfgrass managers prefer creeping bentgrass for superior putting quality and year-round green color, and thus new cultivars are always a topic of interest.

The objective of this study was to evaluate a new experimental bentgrass cultivar ''AU Victory'' in comparison to widely used commercially available bentgrass cultivars, with these cultivars all managed as a putting green.

Material and Methods

The roots of 'AU Victory' date back to the severe Alabama summer droughts of 1999 and 2000. Courses that relied on municipal irrigation water found themselves without a source as the precious resource was diverted for human use. As a result, many greens nearly died or were completely killed, leaving a few surviving clones on each green. While the base cultivar for each greens sampled was known, frequent interseeding makes it virtually impossible to determine the provenance of an individual clone other than to say that it belongs to one of the cultivars in use during the 1980s and 1990s. These clones (300) were collected by the first author and placed in a holding nursery at the Tennessee Valley Research and Extension Center, Belle Mina, AL, for two years. At that time, 150 surviving clones were dug up and send to the 2nd author in Lebanon, Oregon. One hundred clones exhibiting promising turf traits formed the basis of the selection program. Half-sib progeny (HSF) seed was produced during 2003.

These HSF were seeded into 90 x 90-cm plots on a native soil green at the Turfgrass Research Unit (TGRU) on the Campus of Auburn University in autumn 2003. Plots were rated for color and turf quality from December 2003 until October 2004. In late May 2004 data collection began withholding all fungicide applications from this evaluation trial and minimized supplemental irrigation. Very little disease was noted throughout the summer but in October 2004, a severe infestation of dollar spot occurred and HSF could be distinguished based on their reaction to this disease. We selected parents for 'AU Victory' based on (i) a cumulative turf quality score throughout spring-fall and (ii) dollar spot disease reaction in autumn 2004. The study was conducted on an newly renovated nursery putting green located at Farmlinks golf course in Sylacauga, AL (33.117730 N, 86.419794 W). The green was approximately 90% sand and 10% peat (vol/vol). Each bentgrass cultivar (Table 1) was seeded on November 21, 2011 at two rates: 4.9 and 9.8 g m^{-2}. Seed was hand seeded in 3 replicate plots for each cultivar/seeding rate. Shaker jars filled with a 500 g mix of seed and sand were used to ensure a uniform seeding, with seed/sand applied in two directions within each plot. Seeded plots were covered with tobacco-seed row cover (a lightweight spun polyester cloth) until germination and seedling emerge had occurred (~7 d), after which the cloth was removed. Each plot was 1.5 m wide and 3.0 m long and there were 3 replications of each cultivar x seeding rate treatment (Figure 1).

Putting green management was performed by the staff of Farmlinks, and followed the procedures used for the maintenance of a high-quality bentgrass putting green surface at a southeastern golf course. Mowing height was 3.2 mm and the green was mowed 6 of 7 days using a walk behind greens mower. Fungicide, fertilizer and irrigation were all applied to prevent turfgrass stress and disease on a preventative basis.

Beginning in December 2011, establishment data was collected four times, until February 2012. To collect this data a dowel rod with 25 marks was placed randomly four times in each plot. If a piece of grass touched one pre-selected side of the dowel it was counted as a 'hit'. The total number of hits in each plot was calculated to determine percent establishment.

Relative turf color and quality ratings were done blindly, i.e., the rater did not know the location of a given entry. A score of 5 on the 1-9 rating scale was considered a satisfactory score.

In October 2013, 23 months after seeding, three 19-mm diameter plugs were removed from each plot and shoots counted.

Results

The interaction of seeding rate and bentgrass cultivar was never significant (P = 0.05) for any response variable at any measurement date.

Cultivar	Developer/Company
'007'	007 creeping bentgrass (experimental 'DSB') is an advanced generation creeping bentgrass variety developed by the New Jersey Agricultural Experiment Station (Rutgers University) working in cooperation with Richard Hurley, Ph.D. Seed Research of Oregon.
'AU Victory'	Developed at Auburn University, AL in cooperation with Blue Moon Farms, Lebanon, OR from 300 survivors of severe summer droughts in Alabama during 1999 and 2000.
'Crystal Bluelinks'	Tee-2-Green, Hubbard Orgeon
'Focus'	Result of a collaboration between Pickseed and Rutgers University.
'Penn A1'	Tee-2-Green, Hubbard Orgeon
'Penn G2'	Tee-2-Green, Hubbard Orgeon
'T1'	Released in Oct. 2004 by Jacklin Seed by Simplot. Selected from two sources.
'Tyee'	Seed Research of Oregon

Tab. 1: Selected bentgrass cultivars seeded for the evaluation trial, Farmlinks, Sylacauga, AL, 2011.

Fig. 1: Trial area at the Farmlinks Golf Course, Sylacauga, AL on 5 January, 2012, 45 days after seeding.

While there were some initial differences among cultivars all cultivars were > 90% established two months after seeding. The higher seeding rate always resulted in a significantly ($P < 0.05$) denser stand but the difference narrowed from 20% (43 vs. 23%) at the 8 December evaluation to 5% (95 vs. 90%) two months after seeding (data not shown).

Bentgrass color is an important consideration in North America, more so than in Europe. All cultivars had an acceptable color (≥ 6) at all rating times (Table 2). 'AU Victory' often received the top average color rating, receiving the top score at 6 out of 11 ratings; the next closest entries ('007', 'Crystal Bluelinks', 'Focus', 'Tyee') received the top score 2 out of 11 times.

'AU Victory' often had highest turf quality (Table 3), garnering the top score in 8 out of 11 ratings. 'Penn A1' shared the top spot with 'AU Victory' in 3 of those ratings. 'AU Victory' never had an average relative quality score ≤ 6.5 and had excellent quality scores particularly in mid summer to early autumn. These quality ratings confirm an earlier study, where 'AU Victory' was compared to the cultivars 'Dominant', 'LS-44' and 'Providence' on a USGA-type green (VAN SANTEN, 2008; personal communication); in 6 out of 6 ratings over a two-year period 'AU Victory' was top-ranked.

'AU Victory' had the highest average shoot density 23 months after seeding at either seeding rate and was significantly different from 'Penn G2' and 'T1' (Table 4). The shoot density for 'AU Victory' was 23-68% and 17-47% higher than competing cultivars for the low and high seeding rate, respectively. All cultivars in this evaluation belong to the newer high-shoot density class of cultivars (SWEENEY et al., 2001). In the previously mentioned unpublished study, 'AU Victory' had much higher shoot density compared to older cultivars such as 'LS-44' (21%), 'Dominant' (38%) or 'Providence' (67%).

Results obtained in this study corroborate the experience of turf managers and course superintendents who have utilized this new experimental cultivar over the last five years.

Color and quality of the bentgrass cultivars were variable over the rating period, indicating that this study should be continued to evaluate long-term performance of the cultivars. Although there was more rapid establishment of the bentgrass cultivars at a higher seeding rate, previous research indicates that such a seeding rate could eventually create issues with increased disease due to competition and immature plants. Additional shoot and root data is needed.

Cultivar	Initial seeding rate	
	4.9 g m^{-2}	9.8 g m^{-2}
	shoots cm^{-2}	
'007'	23 a	23 ab
'AU Victory'	32 a	28 a
'Crystal Bluelinks'	19 a	no data
'Focus'	23 a	24 ab
'Penn A1'	22 a	24 ab
'Penn G2'	21 a	19 b
'T1'	26 a	19 b
'Tyee'	23 a	23 ab

Tab. 4: Shoot density of creeping bentgrass cultivars, Farmlinks Golf Club, Sylacauga, AL, October 2013.

	Relative quality (1 – 9 scale)										
	2012			2013							
Cultivar	23-Feb	18-Apr	20-Jun	26-Apr	30-May	27-Jun	11-Jul	26-Jul	7-Aug	23-Aug	5-Sep
'007'	7.3 a	6.8 a	7.0 a	7.2 a	7.0 ab	6.5 b	6.8 ab	6.8 ab	6.0 bc	6.8.a	7.2 a
'AU Victory'	7.3 a	6.8 a	7.0 a	7.8 a	6.2 bc	7.7 a	7.5 a	7.5 a	6.5 abc	7.3 a	6.8 ab
'Crystal Bluelinks'	7.7 a	6.3 ab	7.0 a	7.0 a	7.3 ab	6.0 bc	6.3 b	6.3 b	7.0 ab	7.0 a	7.0 ab
'Focus'	7.5 a	6.7 a	7.0 a	7.8 a	6.2 bc	6.7 b	6.3 b	6.3 b	7.2 a	6.8 a	6.7 ab
'Penn A1'	7.3 a	6.7 a	6.3 c	7.7 a	8.0 a	6.5 b	6.5 ab	6.5 ab	6.7 abc	6.8 a	7.3 a
'Penn G2'	7.5 a	6.7 a	6.8 ab	7.3 a	6.5 bc	6.0 bc	6.3 b	6.3 b	5.8 c	6.8 a	6.7 ab
'T1'	7.5 a	6.0 b	6.5 bc	7.2 a	8.3 a	5.5 c	5.0 c	5.0 c	6.8 abc	5.5 b	6.3 b
'Tyee'	7.2 a	6.0 b	7.0 a	8.0 a	5.3 c	6.7 b	6.2 b	6.2 b	6.3 abc	7.0 a	6.8 ab

Tab. 2: Relative color (1 – 9 scale) of creeping bentgrass cultivars managed as a putting green, Farmlinks Golf Club, Sylacauga, AL.

	Relative quality (1 – 9 scale)										
	2012			2013							
Cultivar	23-Feb	18-Apr	20-Jun	26-Apr	30-May	27-Jun	11-Jul	26-Jul	7-Aug	23-Aug	5-Sep
'007'	6.8 a	6.3 a	6.8 a	7.5 abc	5.7 ab	5.8 bc	6.7 a	6.0 b	5.5 ab	6.0 bcd	5.0 cde
'AU Victory'	6.8 a	6.2 ab	7.0 a	8.2 a	6.5 a	7.5 a	6.5 ab	7.5 a	6.2 ab	7.2 a	7.2 a
'Crystal Bluelinks'	6.7 a	6.7 a	7.0 a	7.0 bc	5.0 b	6.3 ab	5.7 bc	7.3 a	5.0 b	5.7 bcd	5.3 bcde
'Focus'	6.7 a	6.3 a	7.0 a	8.0 a	6.2 ab	5.7 bc	6.3 ab	7.5 a	6.2 ab	6.0 bcd	5.7 bcd
'Penn A1'	6.8 a	6.3 a	7.0 a	7.5 abc	6.5 a	5.5 bcd	6.0 ab	7.0 ab	6.0 ab	6.2 bc	6.0 abc
'Penn G2'	6.5 a	6.7 a	6.8 a	7.5 abc	6.0 ab	5.0 cd	4.8 cd	6.2 b	6.2 ab	5.0 d	4.5 de
'T1'	5.8 a	6.2 ab	6.8 a	6.7 c	6.2 ab	4.3 d	4.5 d	6.0 b	6.0 ab	5.2 cd	4.2 e
'Tyee'	6.0 a	5.7 b	6.7 a	7.7 ab	6.2 ab	6.3 ab	5.7 bc	7.5 a	6.5 a	6.3 ab	6.5 ab

Tab. 3: Relative quality (1 – 9 scale) of creeping bentgrass cultivars managed as a putting green, Farmlinks Golf Club, Sylacauga, AL.

Conclusion

This new cultivar has promising characteristics but should be evaluated over a larger range of environments.

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Comparison of white clover cultivars in low input turfs

Hejduk, S. and M. Kvasnovský

Introduction

The introduction of dwarf varieties of white clover (*Trifolium repens* L.) in grass seed mixtures is considered one of the tools for reducing external inputs (irrigation, pesticides, mineral fertilizers) and providing higher level of sustainability. New clover cultivars are selected for homogenous lateral spreading and for balanced growth with grasses (VAN DER HEIJDEN and ROULUND, 2010).

The aim of this research was to compare two cultivars of microclover ('Pirouette' and 'Pipolina', DLF Trifolium, DK), selected for turfgrass use, and two small-leaved forage cultivars ('Klement' and 'Luke', Agrogen, CZ) in a mixture with grasses, grown under low input management in an area with pronounced soil water deficit.

Material and Methods

The experiment was established at the University farm Žabžice (49°0´42´´ N, 16°35′32″ E), Czech Republic and began on June 10th 2010. The area is warm and dry with average yearly precipitation 480 mm and average temperature of 9.2 °C. The soil is classified as haplic chernozem arenic, and contains 55% of sand, 29% of silt and 16% of clay. The available water holding capacity of the top layer (0 – 500 mm) is 11.9%.

The following five variants were tested:

1. Commercial turfgrass mixture (*Lolium perenne* 'Mondial' 30%, *Poa pratensis* 'Panduro' 20%, *Festuca rubra* 'Makyta' 30% and *F. rubra* 'Cinderella' 20%) – further termed as grass mixture (GM)
2. GM + *Trifolium repens* cv. 'Luke' (small leaved forage cultivar, Agrogen, CZ)
3. GM + *T. repens* cv. 'Klement' (small leaved forage cultivar, Agrogen, CZ)
4. GM + *T. repens* cv. 'Pipolina' (microclover, DLF, DK)
5. GM + *T. repens* cv. 'Pirouette' (microclover, DLF, DK)

The turfgrass was seeded at the rate of 20 g m^{-2}, and the white clover was added to the mixes at the one rate of 1 g m^{-2}. The plots were 2 m^2 (2 x 1 m) in size and each variant was repeated three times. The plots were fertilized before seeding by a 20-5-8-2 fertilizer (Lovogreen, Lovochemie Inc.) in the rate of 20 g m^{-2} and again in the same way at the beginning of September 2010. During the establishment year the trial was irrigated when necessary. In 2011, 6 g and 4 g of N m^{-2} were applied as ammonium nitrate in April and June respectively on the plots with grasses only (variant 1); the plots were not irrigated and were mown at the height of 70 mm only once as the growth was limited by the lack of soil moisture.

The compressed height (comprising height and density of sward) of the turf was measured by rising-plate meter (CASTLE, 1976) immediately before the first cut on May 12th 2011, together with visual merit (1= lowest quality, 9 = highest quality), turf cover and diameter of white clover trefoils in variants 2 to 5.

The trefoil diameter was measured, by ruler, on a sample of 15 trefoils per plot. The mean value from each plot was used for statistical analysis. During the growing season measures of the chlorophyll status, by Chlorophyll meter CM 1000, Spectrum technologies Inc., and measures of the turf temperature, at 50 cm from the soil, by thermometer OS 36 Omega, USA, were recorded. Both measures were repeated five times per plots and the mean value from each plot was used for statistical analysis. Readings were taken randomly and as clover and grass were evenly mixed, it was not possible to separate the measures over clover from the ones over grass. Measurements of canopy temperature and chlorophyll status were taken during days with clear sky and when there was water deficit in the soil to emphasize differences among variants.

Statistical analyses were performed using one way ANOVA (Statistica 9.1, StatSoft) with multiple comparisons according to Fisher LSD test ($P < 0.05$).

Results and Discussion

Tables 1 and 2 show the results of measurements recorded in the first year after the establishment. All clovers showed a coverage much higher than their percentage content in the seed mixture (5% w/w).

The forage clovers overtook the grass and possibly should be used at a lower percentage in the seed mix. The presence of clover (2%) in pure grass mixture (GM) was probably caused by the contamination of soil during establishment. Forage clover cultivars grew taller and spread more aggressively than microclovers and pure grass mixture. This can be seen as disadvantage as it implies the need of more frequent mowing (higher costs and fossil fu-

Cultivar	Compressed height	visual merit	Total cover	Clover cover	Trefoil diameter
	(mm)	(1 – 9)	(%)	(%)	(mm)
Grass mixture (GM)	66^{ab}	4.7^{a}	83^{a}	2^{a}	–
GM + Tr 'Luke'	114^{c}	6.7^{b}	96^{b}	79^{d}	44.4^{b}
GM + Tr 'Klement'	113^{c}	5.3^{a}	94^{b}	85^{d}	49.8^{a}
GM + Tr 'Pipolina' (microclover)	72^{b}	8.7^{c}	93^{b}	56^{c}	35.4^{c}
GM + Tr 'Pirouette' (microclover)	56^{a}	5.3^{a}	83^{a}	19^{b}	25.9^{d}
Significance	**	**	**	**	**

Tab. 1: Selected parameters of turfgrasses without a and with microclover measured in 2011 (May 12th).

Cultivar	Chlorophyll status			Canopy temperature (°C)	
	June 23rd	August 4th	August 25th	August 4th	August 25th
Grass mixture (GM)	197ab	312a	236	28.1	42.9
GM + Tr 'Luke'	209bc	386abc	245	26.3	41.9
GM + Tr 'Klement'	233c	461c	247	26.3	42.5
GM + Tr 'Pipolina' (microclover)	200ab	442bc	218	26.5	42.4
GM + Tr 'Pirouette' (microclover)	175a	358ab	190	28.8	43.4
Significance	*	*	ns	ns	ns

Tab. 2: Chlorophyll status and canopy temperature of the turfgrass plots.

els consumption). During spring the cultivar 'Pipolina' ranked the highest in visual merit, while the pure grass mixture appeared the worst, possibly as result of the water deficit after the application of the N fertilizer. Relatively low turf cover was caused by moles activities during winter but was better on plots with higher coverage of clover.

As turf in mix with white clover is continuously supplied by symbiotically fixed nitrogen, available also for grasses, turf appearance is positively influenced (e.g. LEDGARD and STEELE, 1992). When the rate of clover is too low good turf quality cannot be ensured without nitrogen fertilization. NONN (2010) mentioned that optimal coverage of microclover for good quality lawn and low input sport turf without fertilization is about 50%.

The cultivar achieving the lowest coverage was 'Pirouette' (table 1).

Small differences among measurements in August are connected with the turf transition to summer dormancy, following pronounced drought and high temperatures. This was also the reason why only one turf height measure was performed. Due to the transition to dormancy the turf was mown just once.

During autumn 2011 (October and November) voles (*Microtus arvalis* L.) started to damage the white clover in the plots. In April 2012 no white clover plant survived in experimental plots and trial had to be terminated.

Conclusions

There are significant differences among white clover cultivars used for turfs. Cultivar 'Pipolina' provided the highest visual merit, small leaves and low height, on the other hand turf with 'Pipolina' had lower chlorophyll status in comparison with cultivars of forage white clover. Weight proportion of 5% (w/w) clover in the seed mixtures resulted in 79 and 85 % coverage for the forage types, while the microclovers 'Pipolina' and 'Pirouette' reached 56% and 19% coverage respectively. Cultivar 'Pirouette' with the finest texture was the least drought tolerant and showed the lowest coverage share of the turf (low competitive ability). Small leaved forage cultivars 'Luke' and 'Klement' showed faster vertical and lateral growth and were also more drought tolerant.

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Smart irrigation controllers conserve cater while maintaining turfgrass quality

Dukes, M.D. and S.L. Davis

Introduction

Smart irrigation controllers are defined as controllers that "estimate or measure depletion of available plant soil moisture in order to operate an irrigation system, replenishing water as needed while minimizing excess water use. A properly programmed smart controller requires initial setup and will make irrigation schedule adjustments, including run times and required cycles, throughout the irrigation season without human intervention" (IA, 2007). A number of research projects have been conducted and published, documenting the performance of these controllers under research conditions. However, a number of "real world" installations indicate that performance of these devices fall short of the conservation potential seen in research (DUKES, 2012). The two classes of devices that are considered "smart" are soil moisture sensor (SMS) and evapotranspiration (ET) based controllers. The SMS controllers measure soil water content in the irrigated zone and the simplest controllers bypass scheduled time based irrigation cycles when moisture is above a user adjustable threshold. On the other hand, ET controllers come in two types, moisture balance and non-moisture balance. The moisture balance controllers maintain a computation of soil moisture content in the irrigated zone based on estimation of ET, measurement of rainfall and a computed irrigation schedule. The non-moisture balance devices use a measurement of temperature and/or solar radiation to adjust a user input maximum runtime throughout the year. This approach is essentially an automated percentage adjust feature available on most modern irrigation timers.

CARDENAS-LAILHACAR et al. (2008) documented irrigation reduction averaging 72% under rainy conditions using soil moisture sensor controllers compared to an identical irrigation schedule without sensors. There was no difference in common bermudagrass [*Cynodon dactylon* (L.) Pers.] turfgrass quality between the sensor based plots and those with a timed based irrigation schedule. In a later study with the same four brands of SMS controllers compared to a time schedule during dry weather conditions, savings were 34% and 54% for two different monitoring periods (CARDENAS-LAILHACAR et al., 2010). Turfgrass quality was not different and above acceptable limits on all SMS controllers that remained functional during the study. One controller failed early in the study resulting in no irrigation and poor turf quality.

Promising water conservation results have been shown with ET controllers while maintaining good turfgrass quality on research plots. DAVIS et al. (2009) documented an average of 43% irrigation savings using two brands of ET controllers on plots relative to a typical time based schedule. In another ET controller study, irrigation reductions ranged from -20-59% while maintaining good turfgrass quality (St.Augustinegrass [*Stenotaphrum secundatum* (Walter) Kuntze] in both studies) not compromised due the reduction in irrigation (McCREADY et al., 2009). The ET controller with negative "savings" occurred during a dry spring period and was isolated to that one period during the two year study.

In contrast to these promising results from plot-based research on the water conservation potential of smart irrigation controllers, DUKES (2012) documented a number of large-scale implementation studies by utilities. One study in particular documented 6.1% irrigation reduction as a result of utility rebate programs in California for 2294 ET controllers across the state. While this was a significant reduction, it is much less than seen in controlled studies. One reason for the difference between irrigation savings of controlled studies and "real world" installations is identifying customers with potential savings and implementing smart controllers on those sites. Our objective in this study was to evaluate the water conservation potential of smart controllers when implemented at single-family homes identified as having excessive irrigation behavior.

Materials and Methods

Orange County Utilities (OCU) single family home water customers were identified as having excessive irrigation by performing a daily soil water balance calculation for each home over the period of record (2003-2008) thus developing a gross irrigation requirement for each home (ROMERO and DUKES, 2014). Volumetric water billing data were used to estimate irrigation by assuming indoor use of 261 L/d/person (MAYER et al., 1999) and that the remainder was irrigation. To be considered for this study, customers had to have irrigation exceeding the gross irrigation requirement consistently during the historical record.

Ultimately, 167 cooperating customers were recruited with 66 receiving ET controllers, another 66 receiving SMS controllers and 35 homes with no smart technology installed where their irrigation was controlled by their existing time clock. Half of each technology treatment also received a follow-up visit for site-specific programming and in-person tutorial (+Edu). General soil type was a significant factor in irrigation application resulting in the separation of cooperators into two soil types denoted as sand and flatwoods. The sand was classified as a very well-drained soil with low water holding capacity whereas the flatwoods was classified as a well-drained soil with a slightly higher water holding capacity. Irrigation was monitored by a dedicated irrigation meter that reads water volume on an hourly basis and turfgrass quality assessments were conducted quarterly.

Results

To date, irrigation data have been collected from the cooperating homes since January 2012 through June 2013. The technology treatments, with weekly irrigation ranging from 13 mm to 20 mm, applied less than the comparisons (25 mm) in the flatwoods locations (Figure 1). However, in the sand locations the comparisons (31 mm) were not dif-

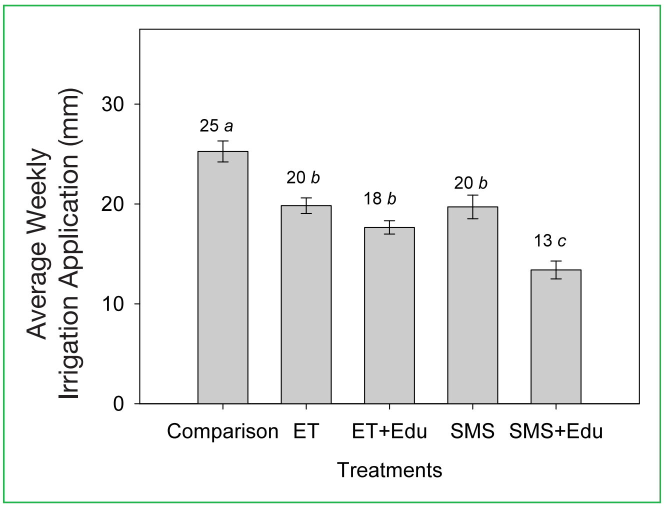

Fig. 1: Average weekly irrigation for each treatment within the flatwoods locations. The error bars indicate a 95% confidence interval from the standard error. Treatments were considered significantly different (differences represented as lowercase letters) if the mean value did not fall within the confidence interval of the average weekly irrigation application of the other treatments.

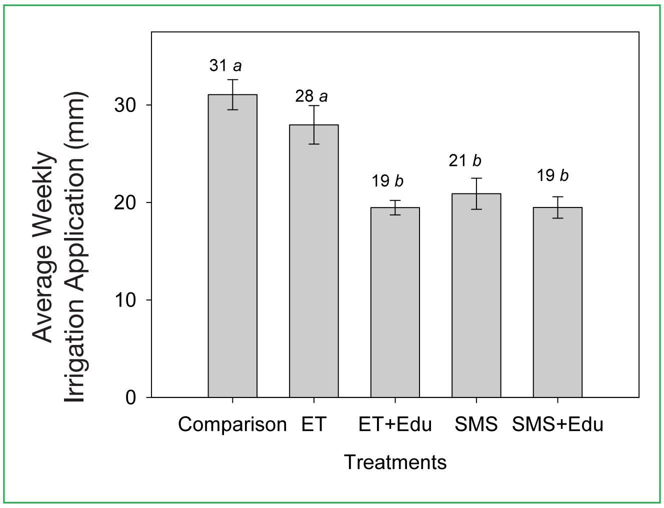

Fig. 2: Average weekly irrigation for each treatment within the sandy locations. The error bars indicate a 95% confidence interval from the standard error. Treatments were considered significantly different (differences represented as lowercase letters) if the mean value did not fall within the confidence interval of the average weekly irrigation application of the other treatments.

ferent from ET (28 mm) (Figure 2). The remaining three technology treatments resulted in less irrigation, ranging from 19 mm to 21 mm.

Conclusion

In this project, we identified utility customers with excessive irrigation based on historical billing data. This identification was critical to implementing smart irrigation control technologies such that irrigation reductions could become a reality with observed savings in this project from 0% (ET, sand) to 48% (SMS+Edu, flatwoods).

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Effects of experimental polymer seed coating on germination and establishment of perennial ryegrass and seashore paspalum under saline irrigation

Alvarez, G., B. Leinauer, E. Sevostianova, M. Serena and C. Pornaro

Introduction

The first seed coatings were introduced to improve the size and uniformity of seed of vegetable crops (KAUFMAN, 1991; ROOS and MOORE, 1975). Since then, coatings have been applied to aid in disease resistance, stimulation or delay of germination and establishment, in otherwise unsuitable soils, among many other recent applications (BERDAHL and BARKER 1980; BRUNEAU *et al.* 1989; SCOTT 1989). In part, due to the fact that establishment by seed remains the most economically feasible method of turfgrass propagation, (BURTON, 1992; CHRISTIANS, 1998; WATSCHKE and SCHMIDT, 1992), the use of coated seed has increasingly become common practice. However, it remains unknown if seed coating can positively affect the germination, emergence, and establishment of turfgrasses under saline irrigation.

Materials and Methods

Two separate controlled environment studies were conducted at New Mexico State University, Las Cruces New Mexico in 2013 to investigate the effects of polymer-coated seed on the germination and establishment of perennial ryegrass (*Lolium perenne* L.) var. 'Bonneville' and seashore paspalum (*Paspalum vaginatum* O. Swartz) var. 'Sea Spray' grown under saline irrigation. Seeds were coated with different co-polymers (ASET 4000, ASET 4001, and ASET 4002) at varying rates. Percentages listed represent fraction of original seed weight added by the seed coating. The experiments were completely randomized with 4 replications. Germination was assessed in a growth chamber (Stults Scientific Engineering Corp., Springfield, IL) using agar solutions at 0, 10, or 20 dS m^{-1}, following published standard protocols (SERENA *et al.*, 2012). Seedling germination was recorded every two days and reported as final germination percentage (FGP). A greenhouse experiment was conducted to evaluate seed emergence (data not presented) and establishment of the two turfgrasses grown in plastic container (15 cm diameter x 12 cm depth) and irrigated with water of 0, 10, or 20 dS m^{-1}. Two soil types were used in this study, a loamy sand and a 1:1 mixture of peat moss and loamy sand (1:1 v:v). Irrigation was applied every other day at 100% reference evapotranspiration (ETo). Plastic containers were fertilized every two weeks at 0.5 g N m^{-2}. Establishment was evaluated as percentage of green cover 130 days after seeding using digital image analysis. The data were subjected to analysis of variance (ANOVA) using SAS Proc Mixed (version 9.3; SAS Institute, Cary, NC) followed by multiple comparisons of means using Fisher's protected least significant difference test at the 0.05 probability level.

Results

Germination: Statistical analysis of FGP revealed a significant interaction between grass species and coating treatment. Perennial ryegrass had greater FGP compared to seashore paspalum (Table 1). Coating with ASET 4002 at 60% reduced germination of perennial ryegrass compared to all other treatments. Generally the experimental coating improved overall FGP of seashore paspalum when compared to the uncoated treatment (Table 1).

Establishment: Statistical analysis revealed a significant interaction of species with all other factors investigated. Some coatings improved establish-

Coating	Seashore paspalum	Perennial ryegrass
ASET 4001 30%	43 de[z]	87 a
ASET 4001 60%	35 ef	91 a
ASET 4002 30%	38 e	89 a
ASET 4002 60%	27 f	78 b
ASET 4002+ASET 4000	54 c	88 a
ASET 4000	50 cd	89 a
Uncoated	26 f	92 a

z Values followed by the same letter are not significantly different from one another (Fisher's protected least significant difference at α = 0.05).

Tab. 1: Final germination percentage (30 days after seeding) of perennial ryegrass and seashore paspalum as affected by seed coatings. Data are pooled over 3 salinity levels (0, 10 and 20 dS m^{-1}) and 4 replications.

Coating	Seashore paspalum			Perennial ryegrass		
	0	10	20	0	10	20
ASET 4001 30%	82 ab[z]	71 bcd	75 abcd	55 a	25 c	5 f
ASET 4001 60%	84 a	67 def	76 abcd	51 ab	23 c	3 f
ASET 4002 30%	83 a	70 cdef	73 abcde	49 ab	21 cd	3 f
ASET 4002 60%	84 a	66 defg	64 defg	51 ab	18 cde	11 def
ASET 4002+ASET 4000	84 a	58 fg	61 efg	53 a	17 cde	6 f
ASET 4000	82 abc	69 def	69 def	49 ab	17 cde	2 f
Uncoated	83 ab	54 g	62 efg	42 b	10 ef	2 f

z Values followed by the same letter (separately for each grass species) are not significantly different from one another (Fisher's protected least significant difference at α = 0.05).

Tab. 2: Turfgrass establishment (percentage of green cover 130 days after seeding) at three different salinity levels (0, 10 and 20 dS m^{-1}) of perennial ryegrass and seashore paspalum as affected by seed coatings. Data are pooled over 2 soil types and 4 replications.

ment both numerically and statistically significant but results were not consistent for all species, salinity levels, and coatings (Table 2). Perennial ryegrass exhibited decreased establishment with increasing salinity levels. However several of the coating materials resulted in in successful establishment of seashore paspalum even at the highest salinity level (Table 2). Soil type did not affect establishment of seashore paspalum, but perennial ryegrass. When data were averaged over all salinity levels, perennial ryegrass reached a coverage of 32% in the sand-peat mixture but only 16% in the loamy sand.

Conclusion

The experiments conducted in controlled environments revealed promising first results on germination and establishment from turfgrass seeds coated with polymers and irrigated with saline water. Real world implications may include reduced irrigation requirement for the germination and establishment of turfgrasses and/or allowing for the use of saline water during establishment. Moreover, such coatings could also allow turf managers to propagate from seed in already salinized soils, which would otherwise be considered impossible to establish turf. However, further research is needed to investigate whether similar results from such coating treatments can be achieved in field trials.

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Developing a yearly aerification program for bentgrass greens located in heat-stressed Environments

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Introduction

The desire to maintain optimal turfgrass and surface properties often leads turfgrass managers to minimize impact from cultural practices. However, cultural practices like hollow tine aerification (HTA) are essential to management of thatch-mat layers, soil aeration, water infiltration, and soil compaction. Proper management of these factors is critical to minimizing summer decline of creeping bentgrass (BEARD, 1997; CARROW, 1996; LUCAS, 1995). Comprehensive research is essential to developing aerification programs which allow optimal use of turfgrass surfaces without sacrificing overall turf health.

A two-year field experiment was conducted on a 14-year-old U.S. Golf Association (USGA)-specified Crenshaw creeping bentgrass [*Agrostis stolonifera* L. var *palustris* (Huds.)] research putting green in Clemson, SC, to evaluate the effects of varying spring HTA size and timing on turfgrass, surface, organic matter (OM), and soil properties.

Materials and Methods

Spring HTA treatments included 1.2-cm i.d. tines spaced at 5.1 cm x 5.1 cm in March and May (standard); 1.2-cm i.d. tines spaced at 3.8 cm x 3.4 cm in March only; 0.9-cm i.d. tines spaced at 3.8 cm x 3.4 cm in March and May; and 0.6-cm i.d. tines spaced at 3.8 cm x 3.4 cm in March, April, May and June. All plots received monthly solid tine aerification during the summer, and a fall HTA application with 1.2-cm tines at 5.1 cm x 5.1 cm. All aerification was to a depth of 7.6 cm, with cores removed. Each of the four treatments was applied to one of four 3.6 m x 3.6 m plots in each of three blocks, resulting in a one-way treatment design and a randomized complete block experimental design.

Turfgrass and surface properties were measured prior the first aerification treatment of each study year and then weekly for 32 weeks. Turfgrass quality (TQ) and recovery (TREC) were rated visually. Turfgrass regrowth (TREG) was measured by placing a 30-cm square template at two areas randomly located in each plot on each rating date. TREG was reported as the percentage of aerification holes where new turfgrass had fully covered the impacted area. Surface compressibility (SC) was measured with a Volkmeter (VOLK, 1972). Surface firmness (SF) was measured as Clegg Impact Value (LUSH, 1985). Ball roll distance (BRD) was measured using a 29-cm modified USGA stimpmeter (GAUSSION et al., 1995). Water infiltration rate (WIR) was calculated from data collected with double-ring infiltrometers.

Thatch mat depth (TMD), thatch mat organic matter content (TOM), soil organic matter content (SOM), dry root weight (DRW), and soil bulk density (BD) were measured prior the first aerification treatment of each study year and then 8, 16, 24 and 32 weeks after initial treatments. TMD was determined from physical measurements of air-dry cores with verdure removed from the surface and loose sand and roots removed below the bottom of the mat layer. SOM was determined from 6-cm deep cores taken between 2 and 8 cm below the soil surface. Thatch with mat OM and soil cores were oven-dried for 48 hours at 60°C, weighed, ashed by placement in a muffle furnace for 2 hours at 550°C, and re-weighed to determine OM content as percentage of weight lost on ignition (ROWLAND et al., 2009; SNYDER and CISAR, 2000).

Results

Varying spring HTA tine size and timing did not affect TQ when averaged across all weekly rating dates in either year (data not shown) nor across all rating dates and both study years (Table 1). Reducing surface area impacted by a single HTA event contributed to increases in TQ, TREC, and TREG up to 4 weeks and decreased the time required for turfgrass to recover to acceptable levels by 1-4 weeks.

Even though surface properties (SC, SF, BRD, WIR) fluctuated significantly, treatment effects were not observed when averaged across all weekly rating dates in either year (data not shown) nor across all rating dates and both study years (Table 2), and lasted less than 2 weeks. Repetitive equal depth aerification did not create a layer of increased compaction.

Plots aerified with 0.6-cm tines had the least 2-year reduction in DRW. Plots

Aerification treatment	Turfgrass quality[1]	Turfgrass recovery[2]	Turfgrass regrowth[3]
	(1-9)	(1-9)	(%)
1.2 cm Mar, May	6.1 a[4]	6.3 a	66.4 ab
1.2 cm Mar	6.1 a	6.8 b	78.0 c
0.9 cm Mar, May	6.0 a	6.5 ab	72.3 bc
0.6 cm Mar, Apr, May, June	5.8 a	6.1 a	65.8 a

1 Turfgrass quality ratings on 1–9 scale with 1 = no live turfgrass and 9 = uniform, dense, dark green turfgrass.
2 Turfgrass recovery ratings on 1–9 scale with 1 = no recovery and 9 = uniform turfgrass with no visual signs of aerification effects remaining.
3 Turfgrass regrowth as percentage of impacted sites fully covered with new turfgrass.
4 Values followed by different letters within the same column are significantly different at the 0.05 significance level.

Tab. 1: Turfgrass properties response to various spring hollow tine aerification treatments on creeping bentgrass greens, averaged across all weekly rating dates and study years, Clemson, SC, March through November 2011 and 2012.

Aerification treatment	Surface compressibility[1]	Surface firmness[2]	Ball roll distance[3]	Water infiltration rate[4]
	(mm)	(g_{max})	(m)	(cm hr^{-1})
1.2 cm Mar, May	3.13 a[5]	76.0 a	1.28 a	79.5 a
1.2 cm Mar 2x	3.23 a	74.9 a	1.29 a	79.3 a
0.9 cm Mar, May	3.09 a	76.1 a	1.30 a	82.8 a
0.6 cm Mar, Apr, May, June	3.11 a	73.1 a	1.29 a	82.2 a

1 Surface compressibility measured as vertical displacement of turf surface due to a compressive force of 570 g cm^{-2}.
2 Surface firmness value quantifies deceleration of 2.25-kg weight dropped from height of 45 cm.
3 Ball roll distance is average of golf balls rolled in two opposite directions from a 29-cm modified USGA stimpmeter.
4 Water infiltration rate measured by the falling head method for a column of water from 8 cm to zero depth.
5 Values followed by same letters within the same column are not significantly different at the 0.05 significance level.

Tab. 2: Surface properties response to various spring hollow tine aerification treatments on creeping bentgrass greens, averaged across all weekly measurement dates and study years, Clemson, SC, March through November 2011 and 2012.

Aerification treatment	Thatch mat depth	Thatch mat OM content[1]	Soil OM content[1]	Dry root weight[2]	Bulk density
	(mm)	(%LOI)	(%LOI)	(g)	(g cm^{-3})
1.2 cm Mar, May	15.8 a[3]	10.77 a	1.45 a	0.082 a	1.30 a
1.2 cm Mar 2x	16.5 b	10.40 a	1.44 a	0.080 a	1.29 a
0.9 cm Mar, May	15.7 a	10.01 a	1.41 a	0.086 a	1.29 a
0.6 cm Mar, Apr, May, June	15.4 a	09.81 a	1.50 b	0.078 a	1.29 a

1 Difference in oven-dry weight and ashed weight as percentage of dry weight lost on ignition (LOI).
2 Oven-dry weight of roots from four 1.9-cm diam. (11.4 cm^2 total surface area), 15-cm deep cores per plot.
3 Values followed by different letters within the same column are significantly different at the 0.10 significance level.

Tab. 3: Organic matter (OM) and soil properties response to various spring hollow tine aerification treatments on creeping bentgrass greens, averaged across all measurement dates and study years, Clemson, SC, March through November 2011 and 2012.

aerified with 1.2-cm i.d. tines spaced at 3.8 cm x 3.4 cm in March only had the greatest reduction in DRW and had the deepest TMD across both years. This treatment would not be advisable on greens where low root mass or thatch accumulation is a concern. Plots aerified with 1.2-cm tines had higher thatch OM content in Year 2 (data not shown). Plots aerified with 0.6-cm tines had higher soil OM content across all rating dates and both study years (Table 3).

Conclusions

Overall, this study suggests an aerification program for bentgrass greens in a heat-stressed environments to include two spring HTAs with 1.2-cm tines at 5.1 cm x 5.1 cm or 0.9-cm tines at 3.8 cm x 3.4 cm (March and May), with monthly summer solid tine aerification and fall HTA.

Turf managers can vary their spring HTA schedule to increase TQ during periods where this is important (e.g. for a tournament). Varying tine size and spacing like treatments in this study will likely only affect surface properties less than 2 weeks, but long-term effects on OM and soil properties should be considered.

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Using metagenomics to investigate the effects of nitrogen and potassium treatments on the microbial rhizosphere community in *Poa annua* turf

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Introduction

Soil nutrient management is an important component of plant disease control. Nitrogen (N) and potassium (K) are known to play a vital role in suppressing disease in a variety of plants (AGRIOS 2005). Anthracnose, caused by the ascomycete fungus *Colletotrichum cereale*, is a destructive disease of *Poa annua* L. f. reptans (Hausskn) T. Koyama] (annual bluegrass) putting green turf that is strongly influenced by N and K (INGUAGIATO et al. 2008, SCHMID et al. 2013). Applying a low rate of N (4.9 kg ha^{-1}) every 7-d has been shown to reduce anthracnose disease severity on *P. annua* compared to the same rate of N applied every 28-d (INGUAGIATO et al. 2008). In another field study, *P. annua* fertilized with N and K exhibited significantly less anthracnose then turf fertilized with either nutrient alone (SCHMID et al. 2013).

While the disease suppressive qualities of N and K have been demonstrated in the field, questions remain about the impact that these nutrients have on *C. cereale* and other microorganisms in a putting green. Microbial communities are capable of adapting to soil nutrient content and have been shown to vary in species composition based on changing soil environments (VAN DIEPENINGEN et al. 2006). Therefore, altering the N and K composition in putting green turf may alter microbial community structure and possibly the distribution of *C. cereale* or other pathogenic microorganisms. In this research, we tested this hypothesis using a metagenomic next generation sequencing approach, allowing a simultaneous, community-wide assessment of the fungi, bacteria and archaea inhabiting the turfgrass rhizosphere. These multivariate data will allow us to determine correlations between N and K on the distribution and diversity of pathogenic and beneficial soil microorganisms in the rhizosphere of *P. annua* turf infected with *C. cereale*.

Materials and Methods

Three soil cores (15.9 mm diameter x 50.8 mm length) were sampled from four replicated experimental plots of *P. annua* maintained at a 2.8 mm cutting height and receiving: (1) an intermediate N rate (132 kg N ha^{-1} yr^{-1}); (2) K alone (200 kg K_2O ha^{-1} yr^{-1}); (3) a combined treatment of N and K (1:1, N:K molar-adjusted ratio; 132 kg N ha^{-1} yr^{-1} and 200 kg K_2O ha-1 yr^{-1}); (4) a low rate of N (100 kg N ha^{-1} yr^{-1}); or (5) a high rate of N (200 kg N ha^{-1} yr^{-1}), for a total of 60 samples. All N and K treatments were applied as urea [$CO(NH_2)_2$] and potassium chloride (KCl), respectively. All plots are naturally infected with *C. cereale*. Soil samples were screened through a 2.5 mm sieve to remove plant matter and large soil particulates. DNA was extracted using the PowerSoil DNA Isolation Kit (Mo-Bio, Carlsbad, CA, USA) and a modified manufacturer's protocol to improve yield and quality. Organism-specific DNA regions were PCR amplified from the ribosomal DNA of fungi (internal transcribed spacer [ITS] region 1 and 2), bacteria (rDNA 16s), and archaea (rDNA 16s), with the addition of an overhang sequence to the locus-specific primers to serve as primer sites in subsequent steps, and to introduce nucleotide complexity into the sequencing process. After purification with the Zymo DNA (PCR) Clean and Concentrator Kit (Zymo Research, Irvine, CA) and pooling of amplicons for each sample, Illumina next generation sequencing libraries were prepared from the resultant amplicon using the Nextera Index Kit (Illumina, San Diego, CA, USA). During this step, unique adaptors and barcodes were added to the DNA to allow multiplexed sequencing. Libraries were normalized, pooled into a single sample, diluted to 20 pM, and denatured for sequencing on Illumina's MiSeq platform using a 600 cycle Illumina v.3 reagent kit. Two genomic DNA libraries and a control phiX library were spiked into the run to introduce complexity. Following sequencing, adapters and barcodes were removed from the reads using the MiSeq Reporter Software. Forward and reverse reads were stitched together and demultiplexed using QIIME (Quantitative Insights into Microbial Ecology, CAPORASO et al. 2010). Operational Taxonomic Units (OTUs) were picked using a 97% similarity threshold in UCLUST (EDGAR 2010). Or 16s data, taxonomic identities were assigned by comparison to the curated Greengenes database (http://greengenes.lbl.gov). For ITS data, taxonomic identities were assigned by using the curated UNITE database (http://unite.ut.ee/repository.php) and a custom turfgrass pathogen database consisting of verified sequence data from twenty fungal turfgrass pathogens. Rarefaction and diversity metrics were calculated at 97% sequence identity.

Results

Amplicon sequencing generated 2.3 x 10^7 reads that passed quality filtering (14.4 Gb of data). After read stitching and demultiplexing, an average of 1.38 x 10^5 sequences were generated per sample. In total, 7.2 x 105 OTUs were identified. Archaea, bacteria, and fungi were identified from all samples. On average, archaea comprised 4.1%, bacteria comprised 26.7%, and fungi comprised 29.7% of the organisms identified. Other organisms (~ 39.5% of the samples) were unidentifiable due to the limited size of the available databases. In all treatments, bacteria dominated the rhizosphere compared to other microorganisms.

Alpha diversity measures from rarified datasets showed that species diversity was highest in low and high N treatments, while diversity was lowest in plots receiving the intermediate rate of N. Detrended correspondence analysis and Kruskal-Wallis ANOVAs revealed significant differences in microbial community structure across all treatments, particularly amongst archaea and bacteria. For example, ammonium oxidizers in the Crenarchaeales dominated K-based treatments, whereas intermediate and high rates of N favored ammonium oxidizers in the Nitrososphareales. The bacterium *Candidatus*

Koribacter, a species capable of cellulose, hemicellulose, and chitin degradation, as wells as nitrate and nitrite reduction, was present in high levels in all treatments.

In the kingdom Fungi, the phylum Ascomycota (sac fungi) was identified most frequently, followed by Chytridiomycota (primarily aquatic fungi), and the Basidomycota (primarily fungi that produce mushrooms). Fungi in the order Helotiales (cup-shaped fungi) and Hypocreales dominated K-based treatments, whereas low and high N treatments favored fungi in the Magnaportheaceae. Using the curated databases for OTU classification, identifications to the genus level were only obtained for well-studies fungi, thus all fungal OTUs were screened against a custom turfgrass pathogen database. Overall, *G. graminis, Magnaporthe poae*, and *Microdochium nivale* were detected at the highest levels. *C. cereale* was detected at low levels (10^{-5}-10^{-6}) in our samples.

Discussion

Using next generation sequencing techniques, we identified a broad range of bacteria, archaea, and fungi from the rhizosphere of *P. annua* turf. Across all treatments, microbial diversity was high, indicating a rich, unique rhizosphere community. Our results show distinct differences in community structure between treatments, suggesting that differing management practices appear to be affecting microbial community diversity and distribution in *P. annua* turf. Many of these organisms possess unique pathways for utilizing different nutrient substrates, thus it remains likely that nutrient cycling processes may vary across treatments. RNA-seq experiments are planned to examine the impacts of these treatments on microbial gene expression levels.

We were unable to determine a relationship between fertility treatments and the distribution of *C. cereale* in the rhizosphere using the current methods. Given the hemibiotrophic lifestyle of *C. cereale*, it is not surprising that only low levels were detected in the rhizosphere, thus analysis of the effects of fertility treatments on *C. cereale in planta* is currently underway. We did, however, observe high levels of the root infecting pathogens *G. graminis* and *M. poae*, demonstrating the utility of rhizosphere metagenomics for examining populations of these fungi in response to environmental variables. The data and techniques described here will serve as a foundation for designing future metagenomic studies for the turfgrass system.

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An investigation of the relationship between golf course irrigation and climate in North Carolina, USA

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Introduction

Golf courses are major water users in many locales around the world. It is crucial for the golf industry to addresses its long-term irrigation needs in concert with other water users. The goals of this research are two-fold: 1) to establish average irrigation rates (megaliters/year/hectare) for golf courses across North Carolina, and 2) to uncover any correlations between irrigation rates and climatic conditions. The hypothesis of this research is that irrigation rates on golf courses are driven by regional climate patterns.

Material and Methods

For this investigation, all irrigation usage data were collected from the North Carolina Department of Environment and Natural Resources from 2007 through 2011 (NCDWR, 2013). To normalize the water withdrawal data on a liters per hectare basis, irrigated land area data were collected for each course in the study through the use of a voluntary survey. The golf courses in the study were divided into four physiographic regions, Mountains, Piedmont, Sandhills, and Coastal Plain. These regions represent inherent differences in climate and landscape for a land area with a nearly 2,100-meter elevation range across 500 km from the ocean to the mountains. The climate in the Mountains and Piedmont regions is cooler and wetter, with lower potential evapotranspiration (PET) than in the Sandhills and Coastal Plain regions.

The respondents to the survey defined the sample size and distribution of the study. To effectively estimate the climatic moisture conditions, the concept of net moisture flux (NMF) was employed. NMF is computed by subtracting the PET from the precipitation at any specific location for any given period of time (FREDLUND et al., 2012). Data were collected from the North Carolina State Climate Office for each of the courses individually over the course of the study period, and then averaged across each physiographic region.

Results

The research found differences in irrigation rates among the four physiographic regions. The differences derive from a combination of varying daily water withdrawals, number of days of irrigation per year, and total irrigable area (Table 1).

To investigate irrigation rates relative to annual climatic conditions, the regional annual average NMF values were plotted against regional annual average irrigation rates in a linear regression model (Figure 1). The Piedmont and Coastal Plain regions were found to have the best regression fit, with r^2 values of 0.95 and 0.96, respectively, while a low regression line fit was observed in the Mountains and Sandhills regions, with r^2 values of 0.52 and 0.78, respectively. Negative NMF values occurred when

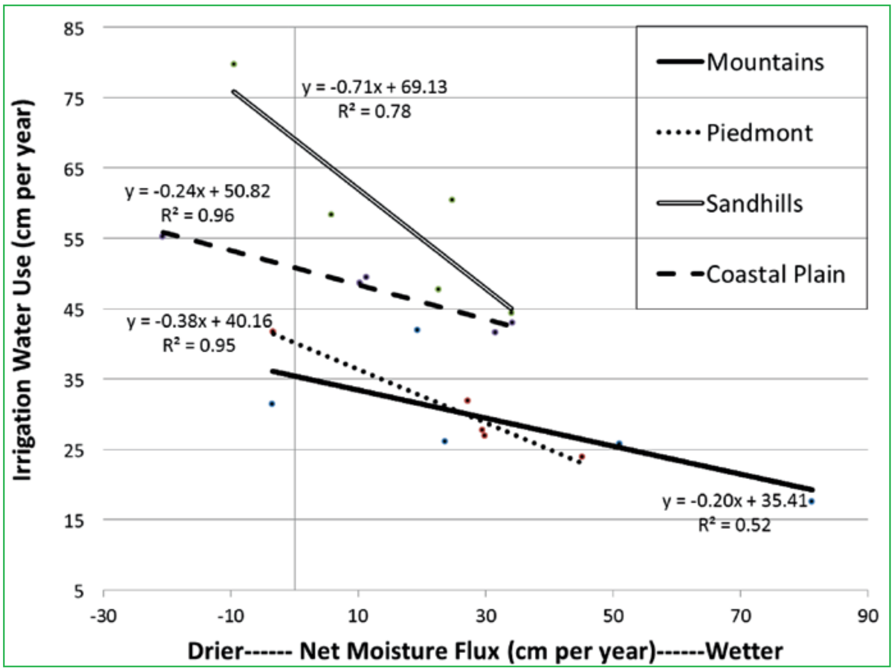

Fig. 1: Linear regression analysis for the net moisture flux and average annual irrigation for each physiographic region.

Physiographic region	n	Average daily irrigation withdrawal (Mld)	Average annual days of irrigation	average irrigated area (ha): greens	tees	fairways	irrgated rough	total	Average water use rates (Mly/ha)
Mountain	26	0.71 (0.60)	131 (89)	1.30 (0.25)	1.18 (0.41)	11.96 (2.96)	13.98 (6.16)	28.41 (6.79)	3.28 (0.88)
Piedmont	55	0.86 (0.61)	138 (90)	1.34 (0.41)	1.62 (0.81)	13.16 (4.80)	20.24 (9.17)	36.36 (9.47)	3.25 (0.84)
Sandhills	26	1.14 (1.00)	153 (87)	1.24 (0.33)	1.67 (0.71)	12.95 (3.40)	14.85 (7.01)	30.69 (6.18)	5.70 (2.19)
Coastal Plain	47	1.10 (1.18)	157 (94)	1.18 (0.24)	1.66 (0.79)	14.03 (5.25)	21.13 (8.55)	39.07 (9.07)	4.42 (1.81)
Statewide	154	0.96 (0.93)	145 (91)	1.27 (0.33)	1.56 (0.75)	13.17 (4.52)	18.51 (8.71)	34.93 (9.35)	3.97 (1.40)

Tab. 1: Five-year average data for irrigation rate calculation including, withdrawal values, number of days, and irrigated acreage. Values in parentheses represent one standard deviation of the average value represented.

PET exceeded precipitation, which approximated drought conditions for the turfgrass. At a NMF of zero, the calculated regression lines predict that individual courses will require an average annual irrigation budget of 35.5, 40.6, 50.8, and 68.6 cm in the Mountains, Piedmont, Coastal Plain, and Sandhills regions, respectively.

Diskussion and Conclusion

From the strong linear regression relationships, climatological diversity explains the annual irrigation differences and demonstrates that irrigation is not steadily increasing or decreasing temporally. The fluctuating irrigation rates are due to regional climate conditions. Furthermore, the unique methodology of assessing changing climate conditions in units equivalent to irrigation usage, allows for duplication under a variety of environmental conditions well beyond North Carolina. Integrating the concepts presented in this research into comprehensive water resource planning could serve to minimize impacts from future water resource shortfalls while maintaining economic vitality and superior conditions for golf courses.

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Integrating host resistance and fungicide for efficient control of dollar spot on creeping bentgrass

Latin, R., J. Daniels and Y. Liu

Introduction

Fungicides are essential for mitigating turf damage caused by a variety of infectious diseases on most golf courses in the northeast quadrant of the U.S. Among the most intractable diseases is dollar spot, caused by a fungal pathogen (*Sclerotinia homoeocarpa* F. T. Bennett) that remains active throughout most of the growing season. Dollar spot often causes only cosmetic (aesthetically unappealing) damage, but under severe conditions, playing surfaces suffer structural damage that may interfere with the lie and roll of a golf ball.

Numerous fungicides are registered for use against dollar spot and, when scheduled according to a sound application strategy, provide satisfactory disease control-even for the most discriminating greens keepers and golf patrons. However, fungicides can be expensive, carry a negative perception in terms of health and environmental risks, and are often vulnerable to the rise of fungicide-resistant populations. Therefore, there is continual pressure to employ non-chemical disease control options. Such cultural control practices include mowing at appropriate heights, fertilizing with appropriate rates of nitrogen, and limiting the duration of the wet period on plant surfaces through the use of fans, or poling and rolling (WILLIAMS et al., 1996).

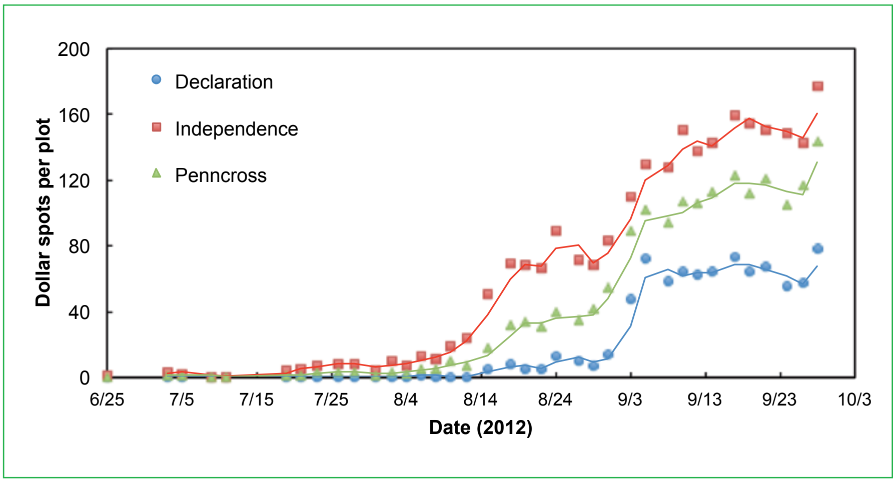

Fig. 1: Disease progress curves recorded during the 2012 growing season illustrate differences in susceptibility to dollar spot among three creeping bentgrass cultivars.

The use of disease resistant cultivars also represents a non-chemical option for reducing disease severity. Real differences in susceptibility to dollar spot are apparent in creeping bentgrass cultivars introduced after the turn of the century (BONOS et al., 2006). Furthermore, some cultivars, such as 'Declaration', consistently exhibited high levels of resistance after comprehensive evaluation (ANONYMOUS, 2008). Like other non-chemical options, the use of less susceptible cultivars reduces disease pressure, and therefore (at least theoretically) allows satisfactory disease control with less fungicide. The notion was examined to some extent (SETTLE et al., 2001), but dollar spot resistance was only moderate at best in cultivars introduced prior to 2001. The objective of this research was to determine if genetic resistance in a modern cultivar such as 'Declaration' could be exploited to achieve satisfactory disease control with less fungicide use.

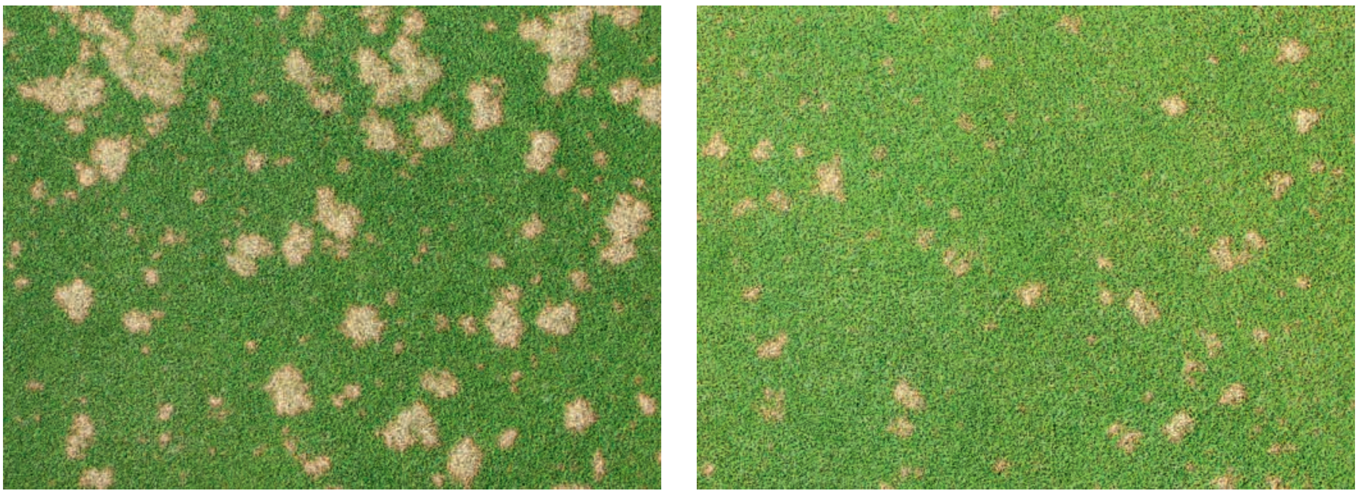

Fig. 2: In plots that were not treated with fungicide, the more susceptible cultivar 'Independence' (left) sustained greater disease severity than 'Declaration' (right).

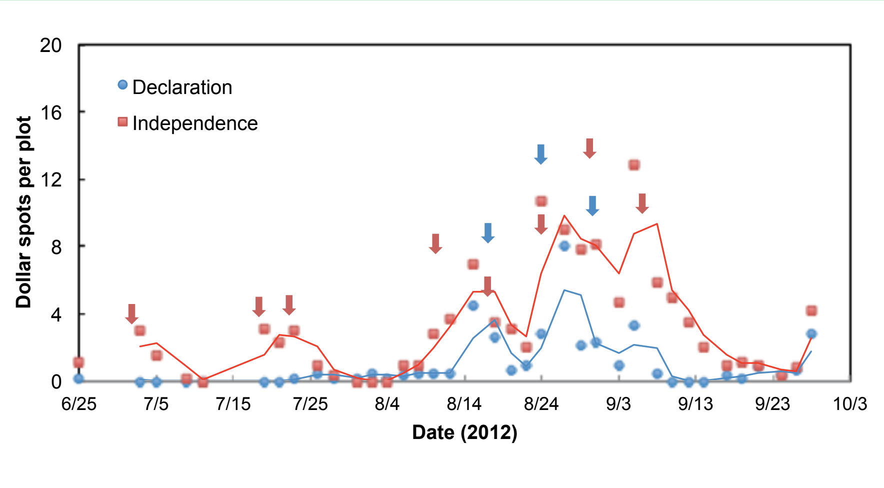

Fig. 3: During 2012, fungicide was applied when dollar spot severity reached a threshold of 3-5 spots per plot. Eight sprays (red arrows) were required on 'Independence'; three sprays (blue arrows) on 'Declaration'.

Materials and Methods

Experiments were conducted in field plots established on a sand-based root zone. Three cultivars of creeping bentgrass ('Independence', 'Penncross', and 'Declaration' – in order from most susceptible to least susceptible to dollar spot infection) were seeded in 1m by 2m plots and replicated three times in a completely randomized design over an area of approximately 0.23 ha. Turf was maintained as a golf putting green and mowed 6 times per week at a height of 0.38 cm. For each year fertilizer was applied monthly (April – September) at a rate equivalent to 24.4 kg nitrogen per ha to total of 146.4 kg nitrogen per season. Irrigation was applied as needed to prevent drought stress.

The fungicide chlorothalonil (Daconil Ultrex, Syngenta) was applied with a custom boom sprayer that delivered a volume of 82.3 L/ha at a nozzle pressure of 2.8 kg/cm^2. The application rates 0, 5.5 kg/ha, and 11.0 kg/ha formulated product (4.5 and 9.0 kg/ha chlorothalonil, respectively) were applied to plots when an action threshold (5-8 spots in 2011, and 3-5 spots in 2012) was observed. Dollar spot severity was recorded by counting infection centers at 2-4 day intervals during the growing seasons of 2011 and 2012. Differences in disease progress and fungicide use were compared among treatments.

Results

In untreated plots, dollar spot severity increased throughout the course of the experiments in both years. Disease progress curves representing dollar spot increase in 2012 show clear differences among the three cultivars (Figure 1). Towards the end of the experiment, Independence suffered more than twice as many infection centers-encompassing significantly greater area compared to 'Declaration' (Figure 2). Less fungicide was required to achieve control on the most resistant cultivar. In a comparison of treatments in 2012, three sprays (Daconil Ultrex at 11.0 kg/ha) were sufficient to prevent disease levels from exceeding the application threshold on 'Declaration' (Figure 3). However, on 'Independence', dollar spot increased to intolerable levels despite the application of eight sprays of Daconil Ultrex at the same rate.

Discussion/Conclusions

These results demonstrate that host resistance in creeping bentgrass cultivars such as 'Declaration' can be exploited to reduce fungicide inputs while achieving acceptable levels of disease control. Our research was conducted on turf maintained at golf putting green height (0.38 cm), but greater benefits should be realized on fairways where mild outbreaks of disease can be tolerated. Given that genetic resistance/susceptibility is a component of disease pressure (LATIN, 2011), results support the principle that less fungicide will be required to control disease under conditions of low disease pressure.

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Potential use of UV C radiation in turfgrass disease management

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Introduction

Disease management represents a significant challenge for farmers at all levels of crop production. Up to now, fungicide applications serve as a major tool to minimise damage and negative influences on crop stand. Those treatments are potentially associated with undesired side effects for human health and the environment (e.g. residues of pesticides in food; high and persistent amounts of copper in the soil). Therefore, the protection and remediation of soil and water resources is a priority of the EU and most national environmental policies. The Directive 2009/128/EC of the European Parliament and of the Council highlights aims and actions to achieve the sustainable use of pesticides. Currently, alternative management practices are strongly supported based on specific national pesticide action networks (e.g. PAN – Pesticide Action Network [UK]; NAP – National Action Plan on sustainable use of Plant Protection Products [Germany]). To some extent, listed challenges are also true for disease management in turfgrass because golf course managers face similar problems to warrant turfgrass stand.

Use of UV C radiation in viticulture

In viticulture a new non-chemical approach to control grapevine diseases has been used successfully at greenhouse and at field trial level. Here, vine canopy and berry surfaces are treated repeatedly with UV C irradiation (254 nm) alone or in combination with reduced fungicide applications (BERKELMANN-LOEHNERTZ et al., 2013; KLAERNER et al., 2013).

Normally, this approach is applied in the food industry and medical technology for surface disinfection of wrapping components and packaging (e.g. plastic beaker, aluminium cover, bandaging material) (BEGUM et al., 2009). The disinfection property is achieved by short time radiation of the target area with tubular UV C lamps at a range of 254 nm (ultraviolet). Here, the biological efficacy reaches at most 99.9 %, depending on quantity and quality of previous microbial spoilage and other technical features.

UV C radiation is an alternative tool also suitable for crop protection purposes. Up to now, this technique was applied particularly in horticultural crops cultivated in protected environments (e.g. Abstracts of the Symposium "ECOFRUIT" at Hohenheim University, Germany, 2010) as well as for greenhouse and nursery sanitation.

In viticulture, the dose-response relationship *in vitro* was elaborated for different propagation units of the target fungi. These data were confirmed *in situ* for pathogen development on potted vines after UV C radiation at different stages of pathogenesis. At host level phytotoxicity was checked. Finally, a large UV C prototype for vineyard application was developed and used for field trials in an experimental vineyard (cv. Riesling) in 2013.

Using UV C technology in viticulture to control downy mildew, powdery mildew and grey mould in the vineyard, the following basic results were obtained:

- different propagation units of the target pathogens are unequal in concern of UV C sensitivity *in vitro*;
- dose-response relationships indicated that the biological efficacy *in vitro* was always less than 100 %;
- in order to ensure a satisfactory biological efficacy in situ on the one hand and to avoid phytotoxicity on the other hand, the applied UV C dose should range between 80 and 160 mWs/cm²;
- the results of the field trial clearly turned out a potential for fungicide reduction;
- no negative side effects on host physiology and must fermentation could be observed.

On going testing on turf

Pathogens relevant to viticulture and turfgrass belong to the same fungal phylum. Therefore, this technique seems generally suitable to control turfgrass diseases, too. The aim of the current project is to adopt and optimise this technology for disease management on golf courses. In order to determine essential technical data for practical use of UV C radiation, research aimed at:

- adoption of the UV C technology used in viticulture for application on golf courses;
- identification of biological effects of different UV C doses to control pathogenic fungi in turfgrass;
- prevention of golf greens from phytotoxicity induced by UV C application;
- quantification of effects generated by UV C radiation on epiphytic, non-pathogenic microbiota present on grass phyllospheres.

Initial experiments in turfgrass showed that it was possible to apply UV C radiation on golf courses by horizontal use of UV C modules from trials in viticulture. Future investigations will focus on pathogenic fungi in turfgrass aimed at disease management with less fungicide input. This technology and first results of UV C application in turfgrass will be presented at the conference.

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Neotyphodium detected in UK turfgrass seeds using Immunoblot analysis

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Introduction

The fungal-endophyte genus of *Neotyphodium* belongs to the *Clavicipitaceous* family that can harbour within the turfgrasses of *Festuca* spp., *Lolium* spp., and *Poa* spp. (CHEPLICK and FAETH, 2009). The vertical transmission of the Neotyphodium hyphae is only via the seed, an exclusive characteristic of the Neotyphodium life-cycle. The hyphae develop intercellularly through the leaf primordial, rhizomes, stolons, sheaths and leaves (CLAY, 1990; SCHARDL et al., 2004). As a mutualistic symbiont, this endophyte most probably obtains photosynthesates in an exchange for defending against a range of biotic and abiotic stresses (LATCH et al., 1985, BREEN, 1994, RAVEL et al., 1997, SCHARDL et al., 2004, KULDAU and BACON, 2008). Hyphae mature in parallel with the life-cyle of the grass and colonise the early development of the seed embryo, ready for transmission into the next progeny. The fungal infection within seeds can be harmed by prolonged warm temperatures, broad spectrum fungicides and life expiration over time (LATCH and CHRISTENSEN, 1982). However, assuming optimal conditions, all seeds of the parent can potentially be infected (BREEN, 1994). *Neotyphodium* has been recorded in many natural situations in the UK and northern Europe (LEWIS and CLEMENTS, 1986, WHITE et al., 1993, BAZELY et al., 1997, SAIKKONEN et al., 2000 and ZUREK et al., 2012). This suggests *Neotyphodium* is commonplace and raises questions about its distribution within UK sports turf.

Neotyphodium could be beneficial for sports turf management especially if reductions in plant protection products can be exchanged for a biological control. To date, there has been limited research to suggest the existence of *Neotyphodium* within UK turfgrass cultivars and it is unclear of the role of endophytes within UK Sports turf. Determining whether endophytes are important requires greater knowledge of their abundance and distribution. The aim of this initial study was to sample a proportion of UK sports turf cultivars for the presence of *Neotyphodium* using a recognised immunoblot kit (HILL et al., 2002 and HAHN et al., 2003).

Materials and Methods

Appropriate sports turf cultivars were selected from the Turfgrass Buyers Guide of the British Society of Plant Breeders (BSPB and STRI, 2012). From the merchants' technical pamphlets, 221 sports turf cultivars were identified. Merchants were then contacted and invited to supply 25 g of seed for each cultivar. One merchant preferred not to participate and four were unable to provide samples in time for testing. Nevertheless, five merchants provided a total of 62 cultivars. Cultivar codes and names have been withheld for commercial reasons.

The immunoblot assay (Phytoscreen seed endophyte detection kit, Cat #EN-DO7971) from Agrinostics Ltd, Watkinsville, GA (www.agrinostics.com) was purchased for detecting *Neotyphodium* in the cultivars of *Lolium* spp., *Festuca* spp. and *Poa pratensis* L. In principle the kits extracted proteins from *Neotyphodium* endophyte and bound them to a membrane. Monoclonal anti-bodies were then stacked with a colour-acting enzyme and washed with a chromogen. A positive reaction was determined by a dark grey colour staining. The kits were optimised by the manufacturer to detect *Neotyphodium* at ≤ 50 ng/seed. For each cultivar, ten seeds were analysed for infection, with 70 seeds placed on to each membrane. A cultivar was determined as positively infected with the minimum of one seed imprinted reaction. Two technicians independently observed the reactions. The seeds and the kits were stored at 4°C prior to use.

Results

The immunoblot kits revealed infection within the cultivars of *Lolium perenne* L., *Poa pratensis* L., *Festuca longifolia* Thuill., *F. rubra* L. ssp. and *L. arundinaceum* Schreb. (Darbysh.). *Neotyphodium* was detected in all of these species. The mean proportion of infected cultivars within each species was 41.9% (1.4±) and the total proportion of infection across all species was 41.8%. The greatest proportion of infection was detected in 18 of the *L. perenne* cultivars, representing almost one-third of the sample for this species.

The cultivars of *F. trichophylla* Ducros ex Gaudin. and *L. multiflorum* Lam. were not infected, however the number of available cultivars for these species was limited (see table 1).

Judging the reaction on the membrane was subjective, therefore careful consideration was required when visually

Species	Number of examined cultivars	Proportion of infected cultivars (%)	Proportion across entire sample (%)
L. perenne	33	54.5	29
P. pratensis	7	42.9	4.8
F. longifolia	2	100	3.2
F. rubra littoralis	6	33.3	3.2
F. rubra subsp. commutata	7	28.6	3.2
F. rubra subsp. rubra	2	50.0	1.6
L. arundinaceum	3	33.3	1.6
F. trichophylla	1	0.0	0.0
L. multiflorum	1	0.0	0.0

Tab. 1: Nine species and 62 sports turf cultivars were tested for *Neotyphodium* infection. The sample represents one-quarter of available UK sports turf cultivars. The proportions of infected cultivars are expressed as infected within species and across the sample population.

Turfgrass diseases, pests and weed control

Plate 1: Nitrocellulose membrane imprinted with the extracted *Neotyphodium* endophyte proteins. The insert shows the imprint of endophyte infected seeds clearly defined as dark colour development. Light colour developments are negative. The subjective output of this test is illustrated here. Seven different cultivars with ten replicates are imprinted here. There are five negative seeds on this membrane underlined in red; these are the known uninfected control seeds.

distinguishing the colour development to assign a positive reaction. Examples of the visual readings are shown on plate 1, the darker grey imprints of lines 3, 4 and 7 were judged as a positive reaction. The lighter imprints on the lines of 1, 2, 5 and 6 were considered as negative. With diligence, two techniques were adopted; 1) to have the results independently and visually assessed by two laboratory technicians and; 2) to allow the imprinted membrane the opportunity to dry at room temperature for three days. With the latter, the imprints became pronounced. The former resulted in a shared median of 3 positive reactions per membrane. The observations were compared using the Mann-Whitney U test, the independent observations were not significantly different (U = 43, $n^1 = n^2 = 9$, $P > 0.05$ two-tail).

Discussion

This is the first reported occurrence of *Neotyphodium* in a range of turfgrass cultivars destined for UK sports turf. The species infected with *Neotyphodium* from this study are comparable with similar grassland species from surveys carried out in Finland and Poland (SAIKKONEN et al., 2000; ZUREK et al., 2012). Although this study has successfully confirmed the use of the Agrinostics kit, it has a certain limitation in terms of sample size, making it difficult for a sufficient conclusion for the abundance of Neotyphodium in UK turfgrass seed. However, it has demonstrated a likelihood that endophyte-infected cultivars are active in UK sports turf, as the cultivars used in this trial are sold in the UK by major seed distributors. To ascertain the importance of endophytes and any associated benefits, there needs to be more research into its abundance and distribution. Future research might also explore where endophytes are having a profound effect on the performance of sports turf, for example an endophyte-mediated resistance to disease, pests, drought or other disorders, such as soil nutrient deficiency.

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Mycorrhizal colonization and competition against annual bluegrass on golf greens with red fescue as the predominant species

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Introduction

National and EU legislations restrict the use of pesticides, fertilizers and water. In this context, red fescue (*Festuca rubra*) species used on greens appears to be the most environmentally friendly cool-season turfgrass species for Scandinavian golf courses due to its low requirements for nitrogen (N) and water and its high resistance to snow moulds (AAMLID et al., 2012). Among disadvantages of pure red fescue is its low density and potential susceptibility to invasion by annual bluegrass (*Poa annua*). Thus, red fescue is traditionally used in mixture with colonial bentgrass (*Agrostis capillaris*). Red fescue in mixture with velvet bentgrass (*Agrostis canina*), which has high density but low requirements to nitrogen and water, is another alternative (ESPEVIG et al., 2011).

The utilization of arbuscular-mycorrhizal (AM) fungi as a method to control annual bluegrass was suggested by GANGE (1998), who reported a negative relationship between the performance of annual bluegrass and the abundance of AM. The degree of AM colonization is favoured by low N and/or phosphorus (P) levels (BLANKE et al., 2011). Mycorrhiza occurs in at least 80 % of all vascular plants and often improves water and nutrient uptake, as well as resistance to biotic and abiotic stresses (KOSKE et al., 1995). Turfgrasses may also benefit from mycorrhiza, and at least 50 % roots of cool-season turfgrasses were reported to be naturally colonized by AM fungi (FRANK, 1984; KOSKE et al., 1995). Inoculation with a commercial source of AM fungi enhanced bentgrass establishment (GEMMA et al., 1997), but its importance on established greens has not been well documented. The objective of this study was to determine effects of mowing heights, N-rate, P-rate and inoculation with a commercial source of AM fungi on mycorrhiza and competition against annual bluegrass on established golf greens with red fescue as the predominant species.

Materials and Methods

The trial was laid out on a 3-yr old USGA golf green at Bioforsk Landvik (58° N). The root zone of 30-cm depth consisted of 90 % sand (volume fraction) and 10 % peat (volume fraction) and had P extractable in ammonium lactate (P-AL) of 1.5 mg 100 g^{-1}. In June 2010, the 4-cm top layer of the green was replaced with the same media as used previously and the green was seeded at a rate of 2.5 kg 100 m^{-2}. A four-factorial experiment was arranged according to a split-split-block design with three blocks. Plots were 1.5 x 1.5 m each. The factors were (i) grass species (whole plots in the direction east-west: pure red fescue (*F. r.* spp. *trichophylla* (40 % cv.'Cezanne') and *F. r.* spp. *commutate* (20 % cv.'Calliope', 20% cv. 'Bargreen', 20 % cv. 'Musica')), 90 % red fescue plus colonial bentgrass (5 % cv. 'Jorvik' and 5 % cv. 'Barking') or 90 % red fescue plus velvet bentgrass (10 % cv. 'Villa'); (ii) *mowing heights* (subplots in the direction east-west: 4.0 or 5.5 mm); (iii) *N-rates* (0.5, 1.0 or 1.5 kg 100 m^{-2} yr^{-1}) and (iv) *P-rates/mycorrhiza* (0 kg or 0.18 kg 100 m^{-2} yr-1 without inoculation or 0 kg 100 m^{-2} yr^{-1} with SYMBIVIT®[1]. Combinations of N-rates and P-rates/mycorrhiza were completely randomized on whole plots in the direction north-south. SYMBIVIT® was applied on 2 June 2011 and 15 May 2012 at a rate of 15 kg 100 m-2 after coring to 6-cm depth using 6-mm hollow tines, and brushed into the wholes. All fertilizers were applied in liquid form; N (ammonium nitrate) and P (85-% phosphoric acid) at 2-wk intervals and K and micronutrients at 4-wk intervals. The green was mown 3 times a week, groomed once a week and subjected to wear from pulling a friction wear roller with soft spikes over the plots 1-3 times a week equivalent to 25.000 rounds of golf per year. The total amount of topdressing applied as pure sand in 2011 and 2012 was 9.50 and 9.25 mm, respectively. Plots were irrigated to field capacity each time the soil moisture at 0-12 cm depth was 8 % or less and also by 5 mm after fertilizing. Annual bluegrass plugs of 56-mm diameter were inserted in the plots on 18 August 2011 and the diameter was measured again by a rule in two directions on 11 October 2012 and the mean value calculated. The turf density and turf quality were recorded monthly from June to October in 2012 using a scale from 1 to 9 (1 – very low, 9 – very high). For the mycorrhiza assay, two soil cylinders of 21-mm diameter and 20-cm depth were taken from plots mowed at 5.5 mm only on September 11th, September 24th and October 1st from blocks 1, 2 and 3, respectively. Roots were washed, cut into 0.5-1.0-cm pieces, cleared in KOH (5 %), rinsed and stained with 0.05-% Trypan Blue (KOSKE AND GEMMA, 1989). The percentage of roots that containined mycorrhizal structures was quantified through a binocular loupe according to the 'grid-line intersect' method (GIOVANNETTI and MOSSE, 1980). On April 2013, samples were taken to 20-cm depth from each plot containing pure red fescue mowed to 5.5 mm for P-AL analyses. The data were analysed using SAS PROC MIXED procedure with random block effects (SAS version 9.2; SAS institute, Cary, NC, USA). The monthly assesments for turf density and turf quality were avaraged prior to analysis. Significant differences among treatments were identified by Tukey-Kramer LSD at the 0.05 probability level.

Results and Discussion

The diameter of annual bluegrass plugs increased on plots with pure fescue but decreased on plots with combinations of red fescue and bentgrasses (Table 1). This improvement in the competitive ability against annual bluegrass seems to be related to an increase in turf density, especially of velvet bentgrass (Table 1). However, the reduction in the diameter of annual bluegrass plugs at 5.5 mm compared with 4 mm was non-significant in spite of the higher density at 5.5 mm than at 4 mm (Table 1). In contrast, a lower N-rate seems to reduce

1 SYMBIVIT® – mycorrhiza inoculum, Norsk Mykorrhiza, Oslo, Norway/Symbiom Ltd., Sazava 170, Czech Republic. SYMBIVIT® contains 15 000 – 25 000 propagules L^{-1} of six *Glomus* spp. (*G. etunicatum*, *G. microaggregatum, G. intraradices, G. claroideum, G. mosseae* and *G. geosporum*)

Factor	Level	Reduction or increase in diameter of annual bluegrass plug %	Density scale 1-9	Mycorrhiza colonization %
Species	Red fescue (RF)	+6.3 a[1]	3.8 c	68.0
	RF+Colonial bent	-2.8 b	5.7 b	63.2
	RF+Velvet bent	-3.8 b	6.3 a	64.7
Nitrogen, kg 100 m^{-2} yr^{-1}	0.5	-4.0	3.5 c	67.9
	1	+1.2	5.5 b	64.4
	1.5	+2.5	6.7 a	63.5
Phosphorus, kg 100 m^{-2} yr^{-1} and inoculation	0	-2.9	5.2	65.8
	0+SYMBIVIT®	-0.3	5.3	65.8
	0.18	+2.9	5.3	64.2
Mowing height (MH), mm	4.0	+2.0	4.8 b	Not studied
	5.5	-2.2	5.7 a	
		Statistical significance of treatment effects		
Species		**	***	NS[2]
Nitrogen		(*)	***	(*)
Phosphorus and inoculation		(*)	NS	NS
Mowing height		NS	***	-
Species x Nitrogen		NS	**	NS
Other interactions		NS	NS	NS

1 The means followed by the same letter are not significantly different according to Tukey-Kramer LSD (α=0.05)
2 NS, not significant at the probability level >0.1.
(*) Significant at the 0.1 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.

Tab. 1: Competitiveness against annual bluegrass, turf density and mycorrhiza colonization as affected by turfgrass species, N fertilization, P fertilization / inoculation with SYMBIVIT®, and mowing height.

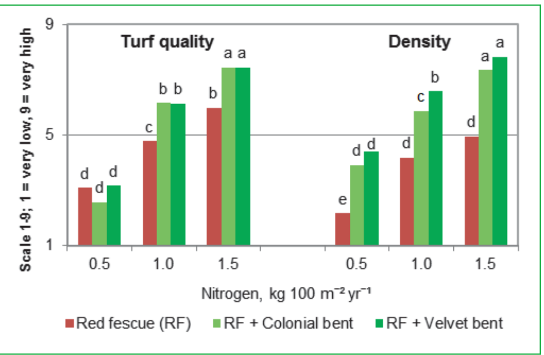

Fig. 1: Turf quality and density of three golf greens with red fescue as predominant species as affected by nitrogen rate. *P*-values are for interaction *Nitrogen x Species*. Bars with the same letter are not significantly different according to Tukey-Kramer LSD (α=0.05).

the competition from annual bluegrass despite a reduction in the density of the pure fescue or fescue/bentgrass combinations. This was most likely due to the high N requirement of annual bluegrass (VARGAS and TURGEON, 2004). Decrease in N level tended meanwhile to increase in the percentage of roots colonized with AM fungi (Table 1). Thus, our results support the theory that abundance of annual bluegrass is negatively related to the abundance of AM fungi in the soil. However, it appears that this is an independent response of both annual bluegrass and AM fungi to low nitrogen, and they are probably not related directly.

Application of P or inoculation with SYMBIVIT® had no effect on turf density or percentage of roots colonized by mycorrhiza, but as with N-rate, an increase in P-rate tended to increased competition from annual bluegrass (Table1). SYMBIVIT® led to a slight increase in the removal of phosphorus from the soil (p<0.001). As measured in April 2013, P-AL was 1.15, 1.03 and 1.61 mg 100 g^{-1} soil in 0-20-cm depth on the plots which did not received P, which received SYMBIVIT® or 0.18 kg P 100 m^2 yr^{-1}, respectively. It seems that the inoculation with AM fungi through top dressing made once a year was inefficient, and that established greens benefit little from such inoculation. Invasive AM fungi were abundant, but seemingly not efficient in providing fescue and bentgrasses a competitive advantage over annual bluegrass, as described by GANGE (1988).

The turf quality was influenced by the same factors as the density (data not shown). A significant interaction *Species x N-rate* revealed that in this study golf greens with red fescue as the predominant species required at least 1.0 kg N per 100 m^{-2} yr^{-1} to produce an acceptable turf quality (p<0.001) and density (p<0.01) (Figure 1).

Acknowledgements

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Changes in sensitivity of the dollar spot fungus, *Sclerotinia homoeocarpa*, to the demethylation inhibitor fungicide Propiconazole 20 years after first use

van den Nieuwelaar, A.M. and T. Hsiang

Introduction

Dollar spot, caused by *Sclerotinia homoeocarpa*, is the most prevalent disease on intensively managed golf courses in the Great Lakes region (SMILEY et al., 2005; HSIANG et al., 1997). There are different approaches to the control of *S. homoeocarpa*, but many superintendents still heavily rely on chemical fertilizers and fungicides to prevent and manage disease symptoms (SMILEY et al., 2005). Demethylation inhibitor (DMI) fungicides are among the most effective for the control of dollar spot; however there have been several reports of fungicide resistance in the US (SMILEY et al., 2005). In Ontario, Canada, a baseline sensitivity study on S. homoeocarpa was completed in 1994 (HSIANG et al., 1997) just before the registration of first DMI fungicide on turf, and then reassessed 10 years later (HSIANG et al., 2007). The objective of this study was to revisit and sample from the same locations as those of the 1993 and 2003 studies, and to see how fungicide use might have affected population sensitivity.

Materials and Methods

From 13 locations in southern Ontario, 100 samples of leaves displaying symptoms of dollar spot were systematically collected in summer 2013 using a grid with at least 1 m between samples. These golf course fairways consisted mostly of *Agrostis stolonifera* with up to a 20% component of *Poa annua*. Fungi were isolated from each grass sample following HSIANG et al. (1997). Each isolate was grown on potato dextrose agar (PDA) for 48 hrs at 22.5 °C, confirmed as *S. homoeocarpa* by comparison with known isolates, and was stored on PDA at 4 °C until testing for fungicide sensitivity.

All isolates were tested for sensitivity to propiconazole, a DMI fungicide commonly used on golf courses in Ontario since 1994. Technical grade propiconazole (Syngenta) was diluted in acetone, and was added to molten PDA (60 °C) to the target concentration of 0.1 µg mL^{-1}, while maintaining an equal final concentration of acetone in the PDA (0.10% v/v) in both fungicide-amended and non-amended PDA plates. Mycelial plugs, 5 mm in diameter, were taken from the edge of active colonies and was placed onto PDA plates amended with or without 0.1 µg mL^{-1} of propiconazole. Note that the label rates for propiconazole application range from 4.0 to 8.0 g per 100 m^2 applied in 3 to 15 L of water, which is equivalent to 270 to 2700 µg mL^{-1}, thousands of times higher concentration than the discriminatory concentration tested. Mycelial growth was measured at 24 and 48 hrs. These measurements were used to calculate

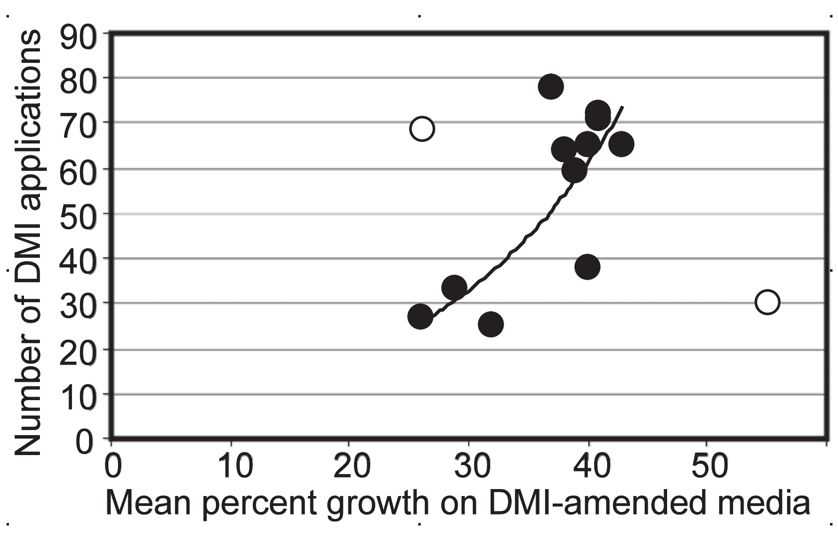

Fig. 1: The average sensitivity toward the DMI fungicide propiconazole of 13 populations of *Sclerotinia homoeocarpa* after 20 years of DMI use. The populations represented by white circles were outliers with the reported number of applications inconsistent with population sensitivity to DMI fungicides. A trendline without the outliers is shown.

Population name	306	307	308	309	310	311	312	313	314	315	095	128	130
Number of isolates	75	87	77	68	83	84	70	95	91	95	93	86	62
Mean growth (%) on fungicide medium[a]	26 h	55 a	41 c	26 h	32 f	29 g	40 c	37 e	39 cd	37 e	39 de	43 b	41 c
Estimated number of DMI applications	69[b]	31[b]	71	27	25	33	38	64	66	78	59	65	72

a Data for growth on medium containing 0.1 µg mL^{-1} propiconazole compared to non-amended medium were subjected to Analysis of Variance, and the means were separated by the test of Least Significant Difference (LSD=1.89, p=0.05), with means followed by a letter in common indicating no significant difference.

b These estimates of DMI fungicide applications are not consistent with the observed fungicide sensitivity, and are considered outliers.

Tab. 1: Population name, total number of isolates tested, mean percent relative growth on fungicide amended media vs. non-amended, and estimated number of DMI fungicide applications at the sampled location over the last 20 years.

the inhibition of growth for every isolate relative to its growth on PDA amended with acetone alone.

Results and Discussion

The mean growth on fungicide-amended media ranged from 26% to 55% of non-amended PDA, and differed significantly (p=0.05) among populations (Table 1). There was no significant relationship between the number of DMI fungicide applications over the last 20 years, and mean relative growth (reflecting the level of reduced sensitivity), with r=0.14 and p=0.65 in a correlation analysis. However since the number of DMI fungicide applications was dependent on self reporting by superintendents and accurate record keeping, this number was examined more closely. There were some apparent outliers in Figure 1 (shown in grey, with relatively low number of fungicide applications, but relatively high levels of reduced sensitivity and vice-versa). When these outliers were omitted, the relationship was found to be significant: r=0.77 and p=0.0058.

In previous years of testing, EC50 values (effective concentrations to cause 50% growth inhibition) were calculated using a wide range of fungicide concentrations (HSIANG et al., 1997 & 2007). Perhaps these more precise estimates of sensitivity are needed to reveal the effects of fungicide use, rather than the use of single threshold concentrations. In any case, greater use of DMI fungicides seems to have been related to decreased sensitivity, although in Ontario, the reduced sensitivity has not resulted in disease control failure.

Conclusions

Isolates with some level of reduced sensitivity were detected among all populations assessed, which may pose a problem for the control of dollar spot disease in Ontario in the future. Further work will be done with the presumed reduced sensitive isolates by determining the EC50 values for these isolates and assessing whether these isolates display a reduced sensitivity to other DMI fungicides and can cause control issues in the field.

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Phosphite mediated inhibition of *Microdochium nivale*

Dempsey, J.J., I. Wilson, P.T.N. Spencer-Phillips and D.L. Arnold

Introduction

The ascomycete pathogen, *Microdochium nivale* (teleomorph *Monographella nivalis* (Schafnitt)) (SMILEY et al., 1992) is causal agent for the most important cool-season turfgrass disease microdochium patch (VARGAS, 2005). Research into novel means to reduce *M. nivale* infection is desirable. Phosphite (PO_3^{3-}) is a reduced form of phosphorus, which has proven efficacy as an inhibitor of phytopathogens (FENN and COFFEY, 1984). The majority of published data however, have been on its inhibitory effects on oomycetes (FENN and COFFEY, 1984, COOK, 2009), although PO_3^{3-} inhibition of ascomycetes has been reported (BURPEE, 2005), including inhibition of *M. majus* (HOFGAARD et al., 2010). DEMPSEY et al., 2012, determined PO_3^{3-} significantly suppressed M. nivale infection in turfgrass ($p<0.01$), compared to controls. Publication of these data led to further field trials and research to determine the mode of suppression. The aims of these studies therefore, were to determine the assimilation, translocation and accumulation of foliar applied phosphite in turfgrass and secondly, to determine any fungicidal or fungistatic properties of phosphite, by assessing the *in vitro* inhibition of *M. nivale* mycelial growth.

Materials and Methods

From 2010 to 2014, field studies, conducted at Royal Curragh Golf Club, Co Kildare, Ireland, were carried out on *Agrostis canina* L., *A. stolonifera* L. and *Poa annua* L. swards, established on a sandy/loam soil, pH 7.1. All plots received granular nutrient inputs (Andersons 21:3:21) at the beginning of May and September each year, at a rate of 30 g m^{-1}, giving annual nutritional inputs (ANI) of 126 kg N ha^{-1}, 7.9 kg P ha^{-1} (in the form of P_2O_5) and 105 kg K ha^{-1}.Treatments, applied sequentially every three weeks, from September to March each year, were arranged in a randomised complete block design (n=6) and comprised of KH_2PO_3 and KH_2PO_4, calibrated to give 0.35g/m^{-1} PO_3^{3-} and PO_4^{3-} (ANI 39 kg K ha^{-1}, 35 kg PO_3^{3-} ha^{-1} and 39 kg K ha^{-1}, 35 kg PO_4^{3-} ha^{-1} respectively). Monthly assessments determined percent *M. nivale* incidence.

Greenhouse pots of *A. stolonifera* (Penn A4) seeded at 6 g m^{-2} and allowed to establish for six months, were used to determine the assimilation and accumulation of PO_3^{3-}, using High Performance Ion Chromatography (HPIC). PO_3^{3-} foliar treatments at 0.35 g/m^{-1}, were applied and leaf, crown and root tissues harvested at 1, 6, 12, 24, 48 h and 1, 2, 3, 4, 5, 6 weeks post-application (p.a.). The tissues were washed in sterile distilled water prior to being dried and ground. Samples (0.5 g) were extracted and injected via 0.47 micron filters into a Dionex ICS100 ion chromatograph. Standard curves prepared from sodium phosphate monobasic anhydrous (H_2NaO_4P) and sodium phosphite dibasic pentahydrate ($Na_2(PHO_3)$ $5H_20$) were used to determine PO_3^{3-} and PO_4^{3-} amounts and reported as ppm dried tissue weight.

In vitro inhibition of *M. nivale* mycelial growth was determined by amending PDA (19 g/l) with H_3PO_3, H_3PO_4, KH_2PO_3, and KH_2PO_4, ranging from 10 to 250 µg/ml^{-1} (n=6). Agar plugs from actively growing colonies, were transferred to amended and control PDA, from which radial growth measurements were used to calculate mean daily growth rates and percent growth inhibition. Data were analysed using SPSS Statistics 19.0 and significant differences separated by Tukey least significant difference test at $p<0.05$.

Results

Field trials determined significantly lower percentages ($p<0.05$) of microdochium patch incidence on PO_3^{3-} treated plots during four seasons, when compared with PO_4^{3-} and control plots (Figure 1). This confirms previously published data which concluded that during periods of disease pressure, sequential applications of phosphite significantly inhibits microdochium patch (DEMPSEY et al., 2012, GOLEMBIEWSKI and McDONALD, 2011).To suppress pathogen activity a compound must be present at the site of infection, Figure 2 shows PO_3^{3-} accumulations in turfgrass tissues over 6 weeks p.a., demonstrating that treated tissues accumulate PO_3^{3-} rapidly and that some is translocated to the roots, suggesting symplastic mobility. The data also indicate that sequential

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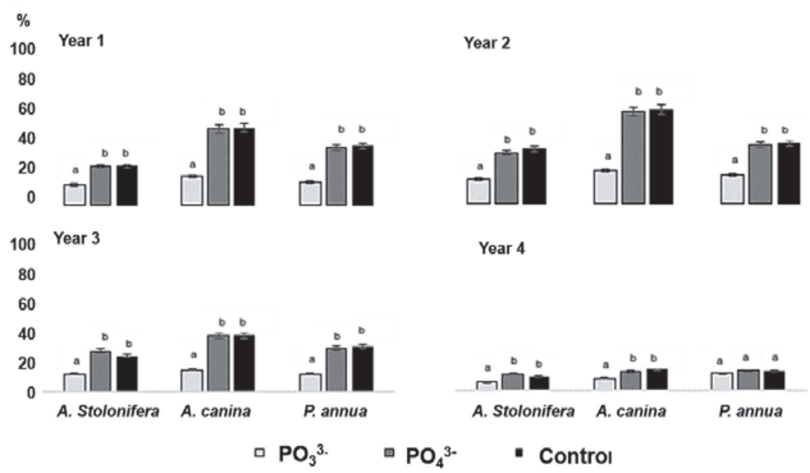

Fig. 1: Treatment effect on microdochium patch incidence on *A. stolonifera, A. canina* and *P. annua* trial plots over four seasons (n=6). Bars indicate one standard error, letters indicate significant differences within species at p < 0.05 according to Tukey least significant difference test.

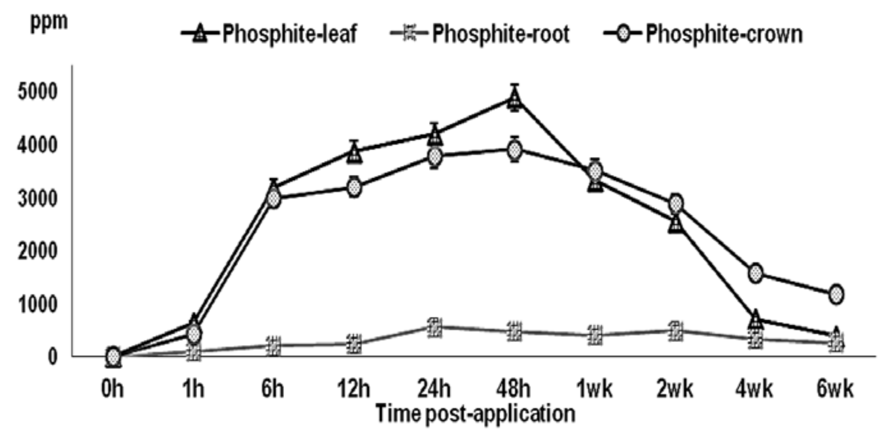

Fig. 2: PO_3^{3-} accumulation in treated tissues 6 weeks p.a. (n=6). Bars indicate one standard error.

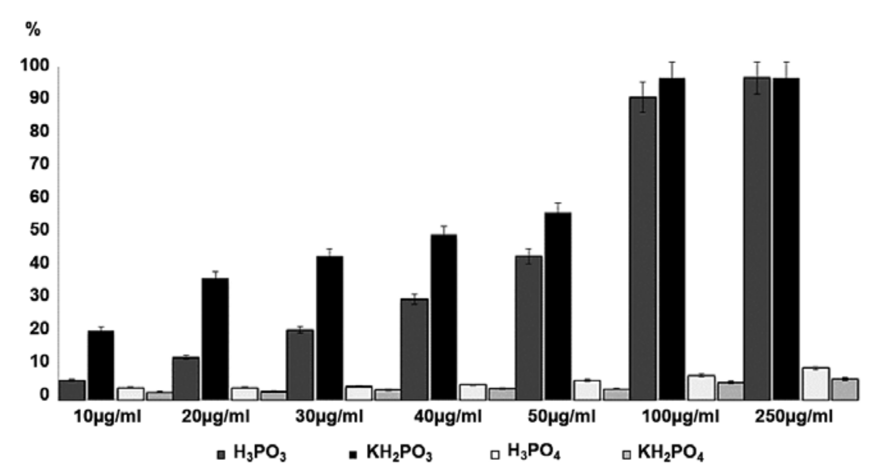

Fig. 3: Treatment effect on percent inhibition of *M. nivale* mycelial growth *in vitro* on amended PDA compared to controls (n=6). Bars indicate one standard error.

applications of PO_3^{3-} on a 3-week cycle would maintain leaf tissue amounts of approximately 2000 ppm. PO_4^{3-} amounts in both treated and control leaf, crown and root tissues were not significantly different, confirming no *in planta* conversion of PO_3^{3-} to PO_4^{3-}. The presence of phosphite in the turfgrass tissues, therefore, would allow for suppression of *M. nivale* upon infection, as evidenced by the *in vitro* experiments, which determined that the presence of PO_3^{3-} in PDA had a direct inhibitory effect on mycelial growth of the pathogen. At 38 µg/ml^{-1} of PO_3^{3-} mycelial growth was reduced to 50% of controls and at amounts of 100 µg/ml^{-1} and above, growth was inhibited by 100%. H_3PO_4 and KH_2PO_4 had no significant effect, with only a 10% growth inhibition at 250 µg/ml^{-1} of PO_4^{3-} (Figure 3). Hofgaard et al., 2010, reported a similar effect in regard to *M. majus*, reporting reduced *in vitro* growth in phosphite amended PDA, concluding that disease development is partly due to a fungistatic effect.

Conclusions

It was concluded that PO_3^{3-} is rapidly assimilated and translocated in turfgrass and that treated plants are significantly less susceptible to *M. nivale* infection in the field. *In vitro* experiments have demonstrated that PO_3^{3-} has a direct inhibitory effect on the mycelial growth of *M. nivale*. Inhibition of mycelial growth *in planta* would allow increased time for initiation of host defences, and the combination of both these direct and indirect effects is likely to contribute to the reduced susceptibility observed. Further research using fluorescent microscopy and spectrophotometry is needed to evaluate secondary metabolic processes and determine the role of PO_3^{3-} in activating or enhancing inducible defence mechanisms.

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Variation in responsiveness of *Agrostis* cultivars to defence activators

Hsiang T., P.H. Goodwin and W. Gao

Introduction

Defence activators control plant diseases by inducing plant defences against subsequent pathogen attack. Some have been shown to decrease severity of several diseases in *Agrostis* species (COOK et al., 2006; CORTES-BARCO et al., 2010; DATNOFF, 2005; LEE et al., 2003; NASH, 2011). The common mode of action of defence activators is either SAR (systemic acquired resistance) via the salicylic acid-dependent pathway, or ISR (induced systemic resistance) via the jasmonic acid and ethylene-dependent pathways, but there appears to be other pathways that are not yet fully characterized (HSIANG at al., 2013). Because these chemicals work by affecting plant defence gene expression, the plant genotype (cultivar) can have a major impact on their effectiveness (i.e., defence activator responsiveness), but this has not been investigated in turfgrasses.

Materials and Methods

Agrostis stolonifera and *A. canina* cultivars tested are listed in Table 1. Mason jars (500 ml) were filled with 70 ml of thrice autoclaved sand rootzone mix, composed of 80% sand plus 20% peat moss (v:v). The soilmix was moistened with 13 ml of sterile de-ionized water to give 26% moisture (w/w). Approximately 0.15 g of seed (up to 300 seeds) were then placed in each jar that was loosely covered with a Petri-plate lid and incubated at 25 C with illumination at 50 µmol/m^2/s.

After 7 days, when leaf blades averaged 2 to 2.5 cm tall, defense activators were applied to plants in each jar. Treatments were 0.75% humic acid-1 (16% humic acid), 0.75% humic acid-2 (15% potassium humate, 12.5% humic acid, Borregaard LignoTech), 33.3 mg/L sodium hyaluronan (United BioScience), 28 mM para-aminobenzoic acid (PABA, Nutritional Biochemicals), 25 mM potassium phosphite (Agromart), or 5 mM silicilic acid hydrate (Alfa Aesar). All chemicals were dissolved in sterile distilled water. Treatments were applied to foliage, except for "5 mM silicilic acid-soil", which was applied to soil (10 ml per jar). For foliar applications, plants were sprayed with 5 ml of activator solution. Control plants were similarly treated with autoclaved distilled water.

Inoculum of *Sclerotinia homoeocarpa* isolate SH84 was produced on wheat seed, dried and ground to fine particles. Plants were inoculated 7 days after activator or control treatment with 0.18 g inoculum per jar, which was 14 days after planting. The jars were then loosely covered with a Petri-plate lid and placed under illumination at 25 C. The per cent foliar yellowing was then visually estimated at 12 days post inoculation (DPI) which was 26 days after planting. Results are the averages from treated plants in three jars compared to the water control plants in three jars.

Results

Although the compounds were applied to plants at seven days after seeding, at which time the tallest plants were on average 2 to 2.5 cm, we expect that some of the applied material continued to persist in the jars, and were taken up by the growing seedlings for the next 7 days before inoculation, with the amounts taken up dependent on the systemicity of the compound and whether they were bound up by the soil. Each activator varied in their effectiveness depending on the cultivar (Table 1). The per cent change in yellowing relative to the water controls are shown and were classified as high control (60% or less of the water control), moderate control (60 to 80%), limited to no control (80 to 120%), or negative control (120% or greater).

The best result for humic acid-1 was high control for Cato, but SR1150 showed negative control. For humic acid-2, the best results were high control for Focus and moderate control for Alpha, Cato, MacKenzie, and Vesper, but there was negative control for Sandhill and SR1150. The best result for hyaluronan was moderate control in MacKenzie, Focus, Alpha, Penncross, T1 and Tyee. At best, PABA only gave moderate control for some cultivars, but it provided negative control for SR1150 which had twice as much yel-

Cultivar	humic acid-1	humic acid-2	hyaluron	PABA	phos-phite	silicic acid spray	silicic acid soil
007	111	100	87	89	91	53	80
Alpha	76	68	74	103	65	45	67
Cato	55	65	100	82	103	53	44
Focus	86	49	70	80	64	70	21
Kingpin	72	83	91	99	96	49	40
MacKenzie	61	61	61	75	61	62	14
PennA4	100	127	79	109	123	27	20
Penncross	82	92	76	75	83	64	44
Sandhill	84	97	112	99	103	29	62
SR1150	137	125	87	194	106	31	44
T1	84	84	74	97	81	42	55
Tyee	75	90	79	75	79	59	55
Vesper	79	77	95	72	75	50	46
LSD (p=0.05)	35	29	32	50	34	41	40

Tab. 1: Dollar spot control in cultivars of creeping bentgrass (*Agrostis stolonifera*) or Vesper velvet bentgrass (*A. canina*) treated with water or a defence activator and inoculated 7 days later with *Sclerotinia homoeocarpa*. Means are per cent change in foliar yellowing relative to the water control at 12 days after inoculation.

Turfgrass diseases, pests and weed control lowing after treatment. Phosphite gave a moderate control for Alpha, Focus, MacKenzie, Tyee and Vesper, but negative control for Sandhill. Silicilic acid applied to foliage had its best results with high control in 007, Alpha, Cato, Kingpin, PennA4, Sandhill, Focus and Penncross, with the rest showing moderate control. Silicilic acid applied to air or soil gave the best results overall with numerous cultivars in the high control category and the remaining in the moderate control category.

Conclusions

All of the activators varied in their ability to induce resistance in the cultivars examined. They provided high control with 60% or less foliar yellowing compared to the water treatment for at least one cultivar, except for hyaluron, PABA and phosphite. However, all were detrimental to resistance (negative control) in at least one cultivar, except for hyaluron or silicilic acid applied by spray or to the soil. This demonstrates the importance of selecting the proper combination of cultivar and defence activator for better turf disease management. In these studies, silicilic acid, applied either as spray or to soil provided the greatest disease suppression. Silicon enters leaves or roots in the form of silicilic acid, and more study is needed on the role of silicon in disease resistance on turfgrasses.

While some cultivars, like SR1150, 007, Sandhill and PennA4, generally responded less well to activator treatments, other cultivars, like MacKenzie and Focus, generally responded well to the different treatments. The cultivars with the least variable response were MacKenzie, Alpha, Cato and Focus. The two with the mostly highly variable response were T1 and Vesper. These results do not support the idea that there is a genetic trait that provides broad scale higher responsiveness to multiple defense activators. Even the response to the same activator, silicilic acid, applied to foliage or soil, differed in effectiveness, which was most apparent for Kingpin and Focus.

All of these results were obtained from laboratory experiments so that the different grasses would be all grown under the same conditions. Future work is needed to examine if these responses are repeatable under the more variable and potentially stressful conditions in the field. Gene expression research using Next Generation Sequencing will also be useful to elucidate the exact mechanisms of action.

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Evaluation of microbiological agents for control of *Microdochium nivale in vitro*

Espevig T., A. Tronsmo and T.S. Aamlid

Introduction

Microdochium nivale causing microdochium patch in the growing season and pink snow mold in spring after snowmelt, is the most important fungal pathogen on golf greens in Scandinavia. Due to the increasing restrictions on the use of chemicals on golf greens (The European Parliament and The Council, 2009), alternative methods for disease control attract more attention. The biological agents Turf WPG and Turf S+, both produced by Verdera (Finland), contain *Gliocladium catenulatum* and *Streptomyces*, respectively. *Streptomyces* strains have shown antagonistic activities against *M. nivale* (TREJO-ESTRADA et al., 1998), and *G. catenulatum* has been reported to suppress some *Fusarium* spp. and *Sclerotinia sclerotiorum* (HUANG, 1978; TEPERI et al., 1998). The main antagonistic mechanisms of *G. catenulatum* and *Streptomyces* are hyperparasitism (MCQUILKEN et al., 2001) and production of antifungal antibiotics (TREJO-ESTRADA et al., 1998).), respectively. Testing of microbiological agents *in vitro* is a useful indicator for their efficacy but such tests are usually performed at temperatures which are optimal for growth of antagonists. The objective of this study was to evaluate the efficacy of Turf WPG and Turf S+ against *M. nivale in vitro* at low temperature which favor attack by *M. nivale* in the field.

Materials and Methods

The treatments included two biological agents, their combination, and two selected fungicides (Table 1). The fungicides were added in amounts necessary to obtain the recommended dose, 1/10 and 1/100 of the recommended dose in 50-% potato dextrose agar (PDA) which had been first autoclaved at 121°C for 15 minutes and then cooled down to 50 °C. The agar with each fungicide was divided among Petri plates (9 cm diameter) at 16 ml per plate. Each microbial agent and their mixture were spread on the solidified pure 50-% PDA with a Drigalski spatula in amounts necessary to obtain the recommended dose, 1/10 and 1/100 of the recommended dose. After all media had solidified, 10-mm-diameter disc from the margin of *M. nivale* (grown on PDA) was placed at the center of each Petri plate. The *M. nivale* strain was isolated from an annual bluegrass (*Poa annua*) green at Landvik. The Petri plates were incubated either at 6°C or at 16°C in the dark for 12 days. On day 4 and 12, the diameter of the *M. nivale* colonies was measured in two directions and averaged prior to further calculations. In control plates with PDA only, the diameter of *M. nivale* colonies was measured on day 4 at 16 °C and on day 12 at 6 °C, and the daily growth rate was calculated. The efficacy of the agents was expressed as reduction of daily growth rate in percentage of control. The data were analyzed using ANOVA for a four-factorial experiment arranged according to a randomized complete three-block design. The experimental factors were: agents, dosages, temperatures and incubation periods.

Results and discussion

Growth rate of *M. nivale* in control plates was 12.8 and 5.0 mm per day at 16 °C and 6 °C, respectively. Both fungicides completely suppressed the fungal growth regardless of dose and temperature (Table 2). After establishment of the antagonists during the first 4 days at 16 °C, the efficacy of the recommended dose of Turf S+ during day number 4-12 was 11 % less than of fungicides and it also decreased with decreasing dose. At 6 °C, 1/1 and 1/10 of recommended doses of Turf S+ had the same effect as at 16 °C, whereas 1/100 dose of Turf S+ had lower efficacy at 6 °C than that at 16 °C. At 16 °C, Turf WPG had the same efficacy as fungicides regardless of dose. However, at 6 °C the suppressive effect of WPG completely disappeared. This significant decrease in antagonistic activity of *G. catenulatum* from Turf WPG at 6 °C was due to a significant reduction in the number of microbes at 6 °C as compared with 16 °C (AAMLID et al., 2013). The stimulating effects of 1/100 and 1/10 dose of Turf WPG on *M. nivale* at 6 °C remained unclear. In our study, the vital activity and antibiotic production of Streptomyces from Turf S+ appeared to persist at 6 °C. In the mixture of Turf WPG and Turf S+

Agent	Active ingredient	Recommended dose per 1000 m²			
		Concentration of active ingredient	Agent, g or mL	Water, L	Recommended concentration, %
Turf WPG (Verdera, Finland)	*Gliocladium catenulatum*	>1*10⁷ cfu[1] per 1 g	100	30	0.33
Turf S+ (Verdera, Finland)	*Streptomyces* spp.	>1*10⁸ cfu per 1 mL	100	30	0.33
Turf WPG + Turf S+	Two above				0.33 + 0.33
Delaro (Bayer, Germany)	Prothioconazole + trifloxystobin	175 g /L + 150 g/L	100	30	0.33
Medallion TL (Syngenta, Switzerland)	Fludioxonil	118 g /kg	300	30	

[1] cfu – Colony forming units (spores or/and mycelium)

Tab. 1: Microbiological agents and selected fungicides used in the study.

Agent	Dose	Temperature and incubation period							
		16 °C				6 °C			
		0-4 D		4-12 D		0-4 D		4-12 D	
		Reduction in radial growth of *M. nivale*, % of control							
Turf WPG	1/100	51	lm[1]	95	abc	46	lmno	-16[2]	s
	1/10	71	hijk	97	ab	43	mnop	-16	s
	1[3]	80	efgh	100	a	53	l	3	r
Turf S+	1/100	45	lmno	66	jk	40	nop	30	q
	1/10	81	defg	63	k	66	jk	65	k
	1	87	cde	89	bcd	69	ijk	89	bcde
Turf WPG + Turf S+	1/100	48	lmn	98	ab	34	pq	38	opq
	1/10	85	def	99	a	75	ghij	70	ijk
	1	81	defg	100	a	82	defg	77	fghi
Delaro	1/100	100	a	100	a	100	a	100	a
	1/10	100	a	100	a	100	a	100	a
	1	100	a	100	a	100	a	100	a
Medallion TL	1/100	100	a	100	a	100	a	100	a
	1/10	100	a	100	a	100	a	100	a
	1	100	a	100	a	100	a	100	a

1 The means followed by the same letter are not significantly different according to Fisher's protected LSD-test (α=0.05).
2 Stimulated radial growth
3 Recommended dose

Tab. 2: Effects of microbiological agents and selected fungicides on radial growth of *M. nivale in vitro*.

suppression of *M. nivale* growth was most likely dominated by Turf WPG at 16 °C and by Turf S+ at 6 °C.

In conclusion, our results suggest that low temperature may reduce the efficacy of Turf WPG. Since *M. nivale* is active during cool and wet periods in the growing season, Turf WPG may be able to reduce the disease pressure in summer and in early autumn. However, Turf S+ may be able to reduce the disease pressure both during the growing season and at low temperature in late autumn.

Acknowledgements

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Frequency and characterization of *Acidovorax avenae* and *Xanthomonas translucens* associated with bacterial etiolation and/or decline on creeping bentgrass putting greens in the Eastern United States

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Introduction

Etiolation, a rapid yellowing and elongation of turfgrass stems and leaves, has been observed for decades; however, the prevalence of etiolation has increased in putting greens within the past few years (GIORDANO et al., 2012). Historically, etiolation on creeping bentgrass (CBG; *Agrostis stolonifera* L.) was transient and non-problematic. Recently, turf practitioners have questioned whether etiolation is associated with bacterial decline and significant turf loss observed on CBG putting greens leading to considerable interest in the etiolation phenomenon. Bacterial pathogens, such as *Acidovorax avenae* and *Xanthomonas translucens*, have been implicated in etiolation and decline of CBG putting green turf. ROBERTS et al. (1981) diagnosed the first bacterial disease on CBG in 1981 where *X. translucens* (reported as *X. campestris* pv. *graminis*) caused bacterial wilt of 'Toronto' (C-15) CBG. Since 1981, reports of bacterial wilt on CBG have been rare, although *Xanthomonas* bacteria remain problematic on *Poa annua* L. f. *reptans* (Hausskn) T. Koyama (MITKOWSKI et al., 2005). *Acidovorax* sp. were shown to cause bacterial brown stripe of CBG in Japan (FURUYA et al., 2009), but these bacteria are more commonly associated with bacterial fruit blotch of cucurbits (WALCOTT, 2005). Due to the rarity of bacterial diseases in turf, management practices to limit disease are not well developed. Although antibiotics can reduce etiolation on CBG, they are not registered for use on turf in the US and chemical control options are limited to plant defense activators (i.e., acibenzolar-S-methyl), surface disinfectants (i.e., hydrogen dioxide) and copper containing products, which have limited efficacy. A thorough understanding of the bacterial pathogens causing etiolation will aid in developing management options for control. The objectives of this research were to determine the frequency of bacteria associated with etiolation and/or decline on CBG turf in the U.S and confirm symptoms associated with *A. avenae* and *X. translucens* infections.

Materials and Methods

During 2011-2013, numerous CBG samples were submitted to the NC State Turf Diagnostic Clinic exhibiting symptoms of etiolation and/or decline. Etiolated tillers were collected from each sample, senescent tissue was removed, and tillers were washed under running tap water for 5 min, surface disinfested in 10% bleach (NaOOH) for 5 min, transferred to 1 mL sterile H_2O, chopped finely with a sterile scalpel, and allowed to stand for 2 min. One loopful of the resulting bacterial suspension was streaked on three nutrient agar (NA) petri plates. Plates were examined for 3 days and representatives of each colony type were transferred to new plates. After isolation, bacteria were identified by polymerase chain reaction and sequencing of the 16S subunit and internal transcribed spacer (ITS) DNA regions using primers 27f + 1488r and 1493f + 23r, respectfully (SCHAAD et al., 2008). Representative isolates of *A. avenae* and *X. translucens* were used to inoculate 4 replicates of 4-wk old 'G2' CBG seedlings. Inoculations were performed by submerging freshly trimmed seedlings in a 10^9 colony forming unit (CFU) ml^{-1} suspension for 5 min, and replanting in 3.5 cm diameter containers filled with calcined clay. Plants were evaluated daily using a scale of 1-9, where 9 represented the best quality and 5 the minimum acceptable quality. Data was analyzed using the GLM procedure in SAS 9.3 for Windows and means were separated using Fisher's protected lsd.

Genera	Number of Isolates	%
Acidovorax	17	9.0
Xanthomonas	7	3.7
Pantoea	30	15.6
Pseudomonas	28	14.9
Microbacterium	14	7.4
Stenotrophomonas	12	6.4
Bacillus	11	5.9
Other	69	36.7

Tab. 1: Frequency of bacteria associated with etiolation and/or decline from 2011-2013.

Results and Discussion

During 2011-2013, 188 bacteria were isolated from symptomatic CBG at 64 locations in the eastern United States. *A. avenae* and *X. translucens* were identified 17 and 7 times, respectively (Table 1). *A. avenae* samples were obtained from Georgia, North Caroli-

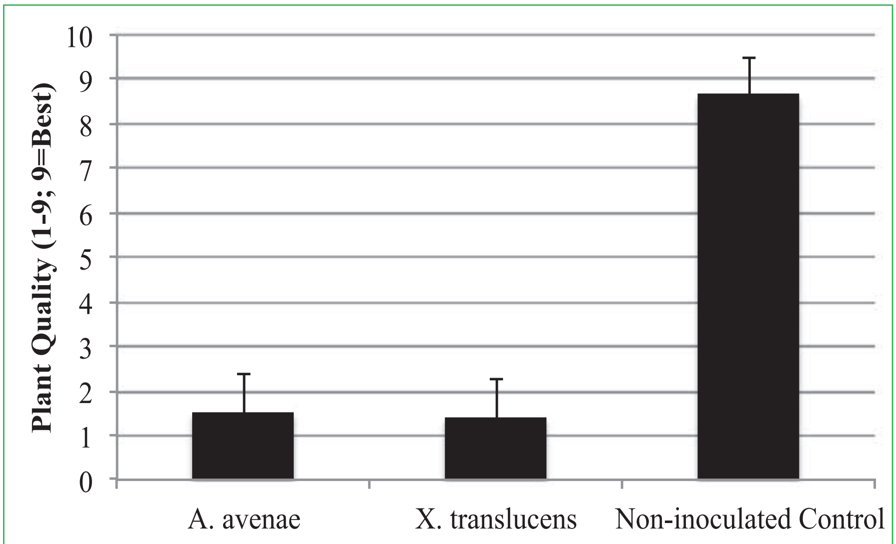

Fig. 1: Influence of pathogenic bacteria on plant quality of G-2 creeping bentgrass turf.

na, Pennsylvania, and Virginia while *X. translucens* was found in North Carolina, Ohio, Kentucky, and Illinois. Additional species included, but were not limited to, *Pantoea, Pseudomonas, Microbacterium*, *Stenotrophomonas*, and *Bacillus*.

Acidovorax avenae and *X. translucens* significantly reduced turf quality within 10 d post-inoculation compared to the sterile H_2O control (Figure 1). Symptoms appeared as dieback from the leaf tip that continued into an overall decline. Additional inoculations have shown both bacteria to cause etiolation and each were re-isolated from their respective inoculated plants.

Results from multiple experiments confirmed the pathogenicity of *A. avenae* and *X. translucens* on CBG. Many graminaceous hosts including corn (*Zea mays*), oat (*Avena sativa*), rice (*Oryzae sativa*), and millet (*Pennisetum glaucum*) are susceptible to *A. avenae*; however, outbreaks are becoming more frequent on these hosts (GIORDANO et al., 2012). It is speculated that extreme environmental conditions may enhance etiolation on CBG but questions remain regarding the bacteria involved (GIORDANO et al., 2012). Seed transmission is a common transport mechanism for *Acidovorax* bacteria but new infections have been reported on established CBG putting greens. Similar questions remain for *X. translucens*. Perhaps recent changes in management practices in the U.S. (e.g., lower mowing heights, increased biostimulant and plant growth regulator use, decreased fertility) may be predisposing turf to bacterial infection. Due to the wide range of bacteria associated with etiolating or declining turf, many bacteria may be involved. The mechanism of etiolation is still unclear but it is apparent that altered plant hormones are involved. Continued research is needed to characterize bacteria associated with etiolation and/or decline and to develop effective control options.

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Ability of some creeping perennial ryegrasses to suppress annual bluegrass germination

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Introduction

Annual bluegrass (*Poa annua* L.) is a cosmopolitan grass of European origin considered one of the most problematical weeds in turfgrasses (DAVID, 2003). In temperate zones, annual bluegrass can be competitive all year round, and represents a serious weed problem for both warm- and cool-season turf species. This grass mainly disturbs intensively managed turfgrasses such as sports turfs, but it often also invades home lawns and recreational areas (McCULLOUGH, 2012). Turf quality is seriously depressed by the presence of annual bluegrass plants, which are light green in colour and produce a large number of showy seedheads that reduce turfgrass uniformity. Likewise, the seedheads reduce playability and performance of putting greens (McCULLOUGH et al., 2005; BROSNAN et al., 2013; BEARD, 2002). Annual bluegrass mainly invades weakened or damaged turfgrasses where the presence of bare soil allows seeds to germinate. The spread is usually quick because of the rapid and abundant seed production regardless of the turf mowing height (LAW et al., 1977; MATTEW et al., 2013). Moreover, the infestation risk is very high as this species can bloom throughout the growing season, albeit peaks occur with cool temperature and short photoperiod (DAVID, 2003). The control of this weed is mainly achieved by cultural and chemical practices. In Europe it is typically controlled using pre-emergence herbicides, plant growth regulators and several cultural practices such as deep and infrequent irrigation, core aerification and verticutting. However, both chemical and cultural control are mostly only effective in the short period, thus much more consideration should be given to preventive management strategies including selection of turfgrass species and cultivars with high competitive ability. It is well known that differences in morphology and canopy traits play a key role in turfgrass resistance to weeds (BEARD, 1973; TURGEON, 2002; BUSEY, 2003), however, little attention has been paid to cultivar morphological properties in preventing annual bluegrass invasion. Breeders have recently developed new cultivars of perennial ryegrass characterized by prostrate growth habit and lateral spreading shoots (creeping-type) that potentially have higher competitive ability than traditional ones. A field study was therefore conducted at Padova University in northeastern Italy to evaluate the ability of creeping-type cultivars to suppress annual bluegrass germination.

Materials and Methods

A field trial was performed from October 2012 to May 2013 at the experimental farm of Padova University in Legnaro, Italy (45°20′ N, 11°58′ E, elev. 8 m) to assess the ability of some creeping-type cultivars of perennial ryegrass to suppress the germination of annual bluegrass. The area has a humid subtropical climate with an average annual temperature of 12.3°C and 826 mm total rainfall. The cultivars used were: CSI (New Orleans in Europe) and PPG-PR 171 (creeping-types), and Azimuth and Presidio (traditional-types). The cultivars were sown on 3 October 2012 at a rate of 25 g m^{-2} in a flat silt loam soil. The experimental design was a randomized complete block with three replications and 2 m^2 plots. An additional plot with bare soil was used as control to determine germination of annual bluegrass without competition from turfgrass. Before sowing, the area was fertilized with 50, 150 and 150 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, plus ammonium nitrate fertilizer (27-N) was applied three weeks after sowing at a rate of 5 kg ha^{-1} of N. During growing periods from 25 October to 30 November 2012 and from 10 March to 30 April 2013, plots were mowed weekly with a rotary mower at a height of 35 mm and clippings were removed. On 5 December 2012, after perennial ryegrass cultivars reached complete establishment, annual bluegrass was sown in a marked area (30x30 cm) in the middle of each plot. From 1 February 2013 (first seed emergence) the number of emerged annual bluegrass seedlings were counted and removed weekly with minimum soil disturbance. Factorial Analysis of Variance (ANOVA) was performed using General Linear Models module of Statistica 7.1 (StatSoft Inc., Tulsa, OK) to analyze the effect of the cultivar on total emerged seedlings. LSD ($P < 0.05$) test was calculated to identify significant differences among means. Percentage of cumulated emergence (cumulated and normalized to 100%) (*CE*) was modelled by a Gompertz function, as follows:

where *a* is related to a time lag before emergence starts, and *b* is related to the slope of the curve.

Weed emergence model performance was evaluated with an efficiency index (*EF*) (LOAGUE and GREEN, 1991), calculated as:

$$EF \quad \frac{\sum_{i\ 1}^{n}(O_i - \bar{O})^2 \quad \sum_{i\ 1}^{n}(P_i - O_i)^2}{\sum_{i\ 1}^{n}(O_i - \bar{O})^2}$$

where *Pi* is the predicted value, *Oi* the observed value, and $\bar{O}$ the mean of observed values. *EF* ranges from 1 to negative value, an *EF*=1 indicates exact predictions.

Results

ANOVA identified a significant effect of cultivar on the annual bluegrass emergence. Mean number of emerged seedlings was higher in traditional turf species than in creeping species (Figure 1). Emergence of annual bluegrass in the Presidio cultivar was significantly higher than in creeping cultivars. The difference between Azimuth and creeping cultivars was not significant, nevertheless it seemed to be more competitive than Presidio, but less competitive than creeping cultivars.

The emergence dynamics of annual bluegrass (expressed as percentage of the total emergence at the end of the season) did not differ in creeping and traditional cultivars, nor in bare soil. It was possible to model weed emergence with just one function, as confirmed by the high efficiency of the estimation (EF=0.96).

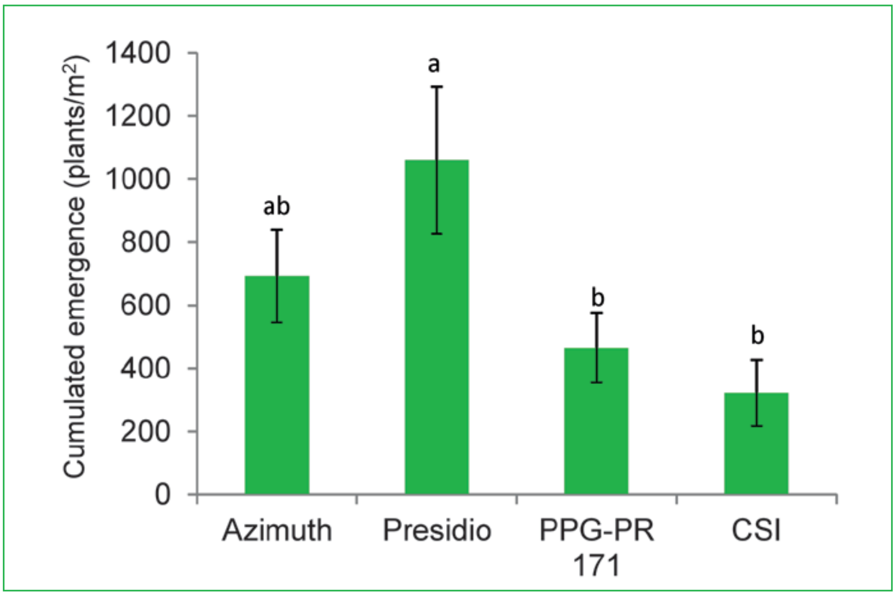

Fig. 1: Cumulated emergence of annual bluegrass in four perennial ryegrass cultivars. Vertical bars represent standard errors, different letters indicate significant differences according to LSD test (P < 0.05).

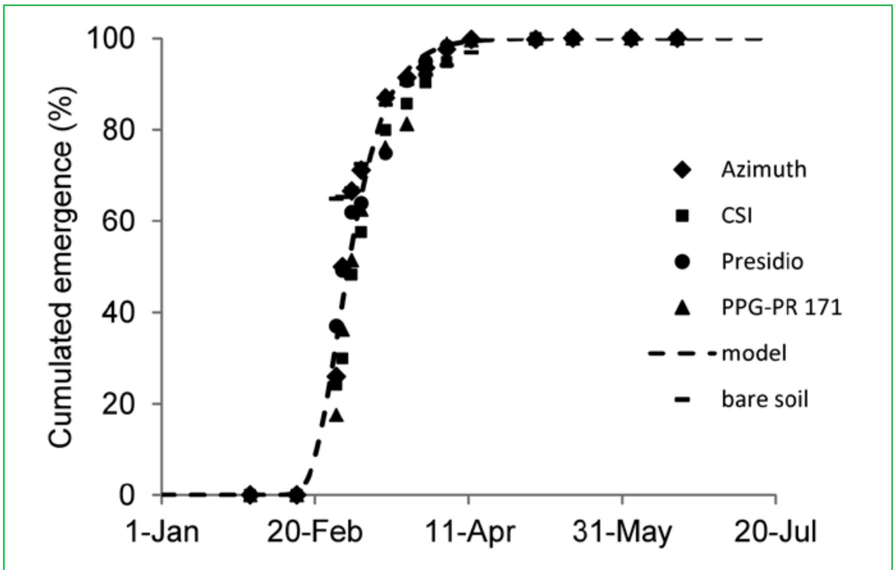

Fig. 2: Emergence dynamics (percentage) of annul bluegrass in four perennial ryegrass cultivars and in bare soil. Observations and model (dotted line). Estimated Gompertz equations for is: CE = 100 · exp (-895.3 · exp (-0.118 · day) (EF = 0.96).

Conclusions

The results on weed seedlings emergence appear to support the hypothesis that the creeping cultivars of perennial ryegrass may reduce annual bluegrass invasion of turfgrass. It seems that differences in morphological features among cultivars affect factors involved in the germination process such as light penetration into the turf canopy and soil temperature.

The same emergence dynamics of annual bluegrass was observed in all the cultivars tested and also in bare soil, therefore a single model was able to describe weed emergence with high performance. These results are very important because it is the first step towards a possible future prediction of emergence dynamics of this species. Emergence prediction is essential for improving the control of weed species by allowing the best treatment timing to be selected, in both pre and post-emergence (MASIN et al., 2005). The fact that cultivars do not influence weed emergence dynamics suggests the possibility of creating a general model suitable in any turfgrass.

The results reported in this paper are from the first year's experiment and further research is necessary to confirm the higher competitiveness of the creeping-type cultivars and to collect other datasets for weed emergence modelling, but the results obtained so far are very encouraging.

Acknowledgments

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Seasonal changes in soil moisture of fairy rings

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Introduction

The turf disease fairy ring is a worldwide phenomenon, occurring frequently on sports pitches, golf courses and domestic lawns. Fairy ring symptoms, which can be caused by a number of different fungus species, can vary from relatively benign circles of mushrooms or puffballs to circles of stimulated turf growth. Some of the more aggressive fairy ring fungi can colonise the soil with their waxy mycelium to the point where it repels water. The failure of water to sufficiently penetrate into the soil profile under these circumstances can induce drought stress and consequential necrosis of the turf. Notoriously difficult to control and widely considered the most damaging form of fairy ring (KEIGHLEY et al., 2013), these circles of bare ground (Figure 1), often in otherwise healthy-looking turf, are termed 'type-1' (SHANTZ and PIEMEISEL, 1917).

Fig. 1: Necrotic circle of turf characteristic of a type-1 fairy ring (Image: STRI)

The key to managing type-1 fairy rings is to prevent soil moisture from dropping beneath the threshold at which water repellency develops through frequent irrigation, aeration, and use of surfactants (CISAR et al., 2000). In the UK, threat of fairy ring damage is thought to be at its greatest in the hotter, drier summer months, when soil moisture is at its lowest. In a recent questionnaire, UK greenkeepers reported that fairy ring symptoms on golf courses are at their worst in August and September (KEIGHLEY et al., 2013). It is, therefore, understandable that focus on type-1 fairy ring management occurs mainly in late summer in response to worsening visual symptoms. Fairy ring symptoms often first materialise in April/May when the fungus becomes active, but what we do not know is how they then develop during their active period to a point where soil moisture levels become detrimental to the turf. This study aimed to investigate the way in which soil moisture in fairy rings changes throughout their active season in comparison with healthy turf.

Fig. 2: Mean soil moisture content of fairy rings compared with an asymptomatic control area on a links golf course in northwest England during the 2013 fairy ring active season of April to November. Error bars represent 95% CI and * indicates p <0.05.

Materials and Methods

Three fairy rings caused by the common type-1 forming fungus Marasmius oreades (Bolton) Fr. (also known as the fairy ring champignon), growing in the sandy soil of a links golf course in northwest England were monitored. The rings, covering areas of 11 m^2, 12 m^2 and 26 m^2, were measured on five occasions on an approximately bi-monthly basis between April and November 2013. A soil moisture meter (originally an ML2x ThetaProbe, which was later replaced with the more robust Fieldscout TDR 100, after testing for consistency) was used to measure moisture content (% volume) of the topsoil at 15cm intervals around the circumference of the fairy ring active (necrotic) zones. For comparison, measurements were similarly taken from an adjacent asymptomatic area of turf. Fairy ring data sets for each month were pooled and statistically compared with the control data using Mann-Whitney U-tests.

Results

Fairy ring active zones were significantly drier than the asymptomatic control area in every month (April, August, October and November p <0.001) apart from June (p = 0.334). This difference was particularly pronounced in April and October, when fairy ring soil moisture was 42.4% and 42.3% drier than the control, respectively (Figure 2).

Soil moisture in the control area was at its lowest in August at 11.45% vol. Whilst soil moisture in the control area had increased by October, the fairy ring soil had become even drier, reaching its seasonal low of 7.96% vol. mean soil moisture.

Conclusion

As soon as fairy rings become active in the spring, soil moisture may already be considerably lower than that of the surrounding healthy turf. Turf managers should, therefore, be aware that moisture deficit may start earlier in the year than originally anticipated. Findings also suggest that soil moisture in fairy ring active zones may continue to decrease even when surrounding healthy turf is appearing to recover. This research reinforces the need to be vigilant of fairy ring soil moisture in order to mitigate symptoms, even at the beginning and end of the season.

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2,4-D and azoxystrobin bioremoval capacity of aquatic plants

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Introduction

A national-scale survey of surface water pesticide contamination recently reported by the United States (US) Geological Survey found one or more pesticide or pesticide metabolites in > 90% of the 186 test sites (USGS, 2006). Results from this survey are concerning for aquatic ecosystem health in urban areas, as detection of pesticides in water samples exceeding an aquatic-life benchmark was > 25% greater in this land use compared to samples collected in agricultural, undeveloped, and mixed-use sites (USGS, 2006). Once inadvertently introduced into surface water bodies, pesticides may cause adverse effects on aquatic fauna and flora health (BOUTIN et al., 2000; VAN DIJK et al., 2013). Therefore, research was conducted to evaluate the pesticide bioremoval capacity of wetland plant species native to the southeast US.

Materials and Methods

Greenhouse research (Method Road Greenhouses, Raleigh, NC, USA) was initiated to evaluate the potential for various aquatic plant species native to the southeast US to reduce pesticide residues in water over time. Plant species included arrow arum (*Peltandra virginica* L.), pickerelweed (*Pontederia cordata* L.), and Virginia iris (*Iris virginica* L.). Plants were established in plastic containers (729 cm^2 surface area; 3,000 cm^3 volume) with a known mass of sandy soil (98% sand, 2% silt/clay w w^{-1}; 2% organic matter w w^{-1}). Plants were grown for 2 months under greenhouse conditions (32/27 C; 14 hour day length) in locally collected water (Raleigh, NC, USA) with nondetectable 2,4-D and azoxystrobin concentrations. Prior to experiment initiation, plant containers were emptied, cleaned, and refilled with 3 L fresh pond water with confirmed nondetectable 2,4-D and azoxystrobin residues.

Pesticides included 2,4-D and azoxystrobin applied at 15 mg ai plant container^{-1} to create a 5 mg L^{-1} pesticide concentration at trial initiation. The initial concentration was selected to provide sufficient residues for screening plants abilities to remove pesticides from water at amounts exceeding detection limits. Applications were made by syringing 20 mL of a stock pesticide solution over the water surface. Water within containers was stirred routinely throughout the experiment and samples were collected 0, 1.75, 3.5, 7, 10.5, 14, and 28 days after treatment (DAT). At 14 and 28 DAT destructive sampling occurred to quantify pesticide residues in above-ground biomass, below ground plant structures, and soil. Pesticide residues were quantified in all matrices using HPLC-DAD methods.

A 3 by 2 factorial treatment arrangement of three aquatic plant species (arrow arum, pickerelweed, or Virginia iris) and two pesticides (2,4-D or azoxystrobin) was evaluated over four replicates in a randomized complete block design. Nontreated-planted and nontreated-nonplanted containers were included for pesticide bioremoval quantification. Data were subjected to ANOVA (P = 0.05), with pesticide and plant species considered fixed effects. Means were separated according to Fisher's protected LSD (P < 0.05) with the use of SAS general linear models.

Results

Pesticide residues in water of planted containers were consistently lower than nonplanted containers from 7 to 28 DAT. In general, 2,4-D remained higher than azoxystrobin in planted containers over this period of time. Due to transpiration from planted containers, water volumes were greater in nonplanted containers over the course of the experiments. Therefore, water concentrations were converted to a pesticide mass within a container at each sampling date and mean separation was conducted using adjusted data.

Overall, Virginia iris reduced 2,4-D in water significantly more than arrow arum and equal to pickerelweed from

Plant	2,4-D			Azoxystrobin		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
	%					
Arrow Arum	15	77	74	21	99	98
Virginia Iris	27	76	92	45	95	99
Pickerelweed	21	78	77	37	99	98
$LSD_{0.05}$	11	NS	3	6	NS	NS

[a] Abbreviation: DAT, days after treatment.
[b] % reduction = [100 x (1 – (mg ai within planted container / mg ai within nonplanted container))]

Tab. 1: Reductions in 2,4-D and azoxystrobin in water relative to nonplanted containers 7, 14, and 28 DAT.[a,b]

Plant	Above-ground		Below-ground	
	14 DAT	28 DAT	14 DAT	28 DAT
	%			
Arrow Arum	2.1	0.1	1.2	1.7
Virginia Iris	3.1	3.2	3.8	4.0
Pickerelweed	17.5	3.6	1.0	4.9
$LSD_{0.05}$	2.9		3.0	

[a] Abbreviation: DAT, days after treatment.

Tab. 2: Percent of 2,4-D in above- or below-ground biomass relative to the initial mass applied.[a]

Plant	Above-ground		Below-ground	
	14 DAT	28 DAT	14 DAT	28 DAT
	%			
Arrow Arum	0.7	1.7	1.3	0.6
Virginia Iris	0.8	2.1	0.4	0.3
Pickerelweed	5.0	2.6	0.3	1.8
$LSD_{0.05}$	1.5		1.5	

[a] Abbreviation: DAT, days after treatment.

Tab. 3: Percent of azoxystrobin in above- or below-ground biomass relative to the initial mass applied.[a]

7 to 28 DAT. At 7 DAT, 2,4-D reductions across species ranged from 15-27% relative to nonplanted containers (Table 1). At 28 DAT, reductions in 2,4-D in water were greatest for Virginia iris (92%), followed by pickerelweed (77%), and finally arrow arum (74%). Within azoxystrobin, differences among species were only detected at 7 DAT. As with 2,4-D, Virginia iris (45%) reduced azoxystrobin significantly more than pickerelweed (37%) and arrow arum (21%). At 14 and 28 DAT, all plant species reduced azoxystrobin > 95% relative to nonplanted containers.

At 14 DAT, 2,4-D in pickerelweed above-ground biomass (17.5% of initial) was more than five times greater than arrow arum and Virginia iris (Table 2). 2,4-D in pickerelweed above-ground biomass declined 13.9% over the following 14 days. Reductions in 2,4-D from 14 to 28 DAT were not detected in arrow arum or Virginia iris above-ground biomass, suggesting metabolism and/or translocation between species varied. No differences were detected between plant species below-ground biomass 14 DAT, while only slight differences were detected between pickerelweed (4.9%) and arrow arum (1.7%) 28 DAT. Interestingly, while 2,4-D in above-ground pickerelweed biomass declined from 14 to 28 DAT, it increased in below-ground plant structures from 14 (1%) to 28 DAT (4.9%). This may be due to differential metabolic degradation rates in above- and below-ground biomass.

Trends regarding azoxystrobin in above- and below-ground biomass were nearly identical to 2,4-D (Table 3). Pickerelweed above-ground biomass contained 5% of initial azoxystrobin, while arrow arum and Virginia iris were 0.7 and 0.8%, respectively, 14 DAT. As with 2,4-D, azoxystrobin in above-ground pickerelweed biomass declined from 14 (5%) to 28 DAT (2.6%), while arrow arum and Virginia iris slightly increased over time. Finally, no biologically significant differences were detected regarding azoxystrobin in below-ground plant structures 14 and 28 DAT.

Conclusions

Data suggested azoxystrobin was more readily removed from water by evaluated plants compared to 2,4-D. Overall, pesticide reduction in water from the evaluated species ranked Virginia iris > pickerelweed > arrow arum. Finally, pesticide residues in plant biomass revealed differential absorption, translocation, and/or metabolism of each compound among species. Information from this research may help select plant species that are best suited to mitigate adverse effects from upslope pesticide-treated turfgrass areas. Future research should evaluate the potential for pesticides stored in aquatic plant biomass to release into water over time.

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Effect of a humectant and two wetting agents on soil moisture content and hydrophobicity on creeping bentgrass and bermudagrass putting greens and sports pitches

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Introduction

A "humectant" is a substance which can attract and retain moisture from the air, thus promoting soil moisture retention (MERRIAM-WEBSTER, 2011; McCARTY, 2011). The Hydretain ES Plus product label suggests watering can be reduced by 50% following mixing soil with the humectant from attracting moisture from humid air. These have been used throughout Germany as a possible approach to water conservation on golf courses and sports pitches due to irrigation restriction (PAEBENS et al., 2010). Wetting agents are commonly applied to alleviate moisture stress as they reduce the surface tension of liquids and therefore soil hydrophobicity (McCARTY, 2011). The objectives of this research were to:

1. Evaluate a commercial humectant (Hydretain ES Plus) and a commercial wetting agents (Cascade Plus) under two irrigation regimes light and frequent, and deep and infrequent on a creeping bentgrass (*Agrostis stolonifera* L.) putting green.
2. Investigate the effects of Hydretain, Cascade Plus, Primer Select, and Primer Select + the fungicide, flutolanil, for control of fairy ring (*Lycoperdon* spp.) and localized dry spots (LDS) on a 'TifEagle' bermudagrass (*Cynodon dactylon* L. Pers. X *C. transvaalensis* Burtt-Davy) putting green.
3. Evaluate the effect of Hydretain, Cascade Plus, and Primer Select on soil moisture retention on a non-irrigated common bermudagrass (*C. dactylon* L.) sports pitch on a native soil.
4. Evaluate soil moisture retention in a soil: humectant mixture following exposure to low (40%) and high (80%) relative humidity.

Materials and Methods

Objective 1: The humectant (Hydretain ES Plus, 287 ml 100 m^{-2}) and wetting agent (Cascade Plus, 255 ml 100 m^{-2}) were applied in 374 L ha^{-1} water to a 'L-93' creeping bentgrass putting green. Hydretain was applied only once, but Cascade Plus was applied as two sequential applications according to product label recommendations. Two irrigation regimes were evaluated for each product similarly to FU and DERNOEDEN, 2009, namely deep and infrequent (DI) with 13 mm of water at first visual sign of wilt, and light and infrequent (LF) with daily ET replacement. Daily ET levels were determined using an on-site weather station.

Objective 2: Hydretain, Cascade Plus, Primer Select, and Primer Select + flutolanil (Prostar 70WP, 1.4 g a.i. m^{-2}) were applied similarly as stated above. The combination treatment of Primer Select and flutolanil was included as flutolanil is a fungicide used to control fairy ring (Photo 1). Applications followed KARCHER et al., 2008. Fairy ring was present at the beginning of the study, and plots were arranged such that each plot contained an equal proportion of visible symptoms. All treatments were irrigated after application with 1.25 cm and mowing was avoided for 24 hrs. Fairy ring and LDS intensity were quantified with line intersect counts using a 1.5 x 1.5 m grid and reported as a percentage.

Objective 3: The effect of Hydretain, Cascade Plus, and Primer Select on soil moisture retention was evaluated on a non-irrigated common bermudagrass sports pitch maintained on a Toccoa soil type [Coarse-loamy, mixed, active, nonacid, thermic Typic Udifluvents] (USDA 2013). Treatments were applied similarly as previously described and immediately prior to predicted rainfall events. Soil volumetric water content (VWC) in the top 10 cm was measured (mass water content x soil bulk density) for 35 days following treatment.

Objective 4: Thirty ml of Hydretain, Cascade Plus, de-ionized (DI) water, or tap water were mixed with 100 g of ground, dry, homogenized 50% sand: 50% clay soil (by volume) with a bulk density of 0.19 g cm^{-3} and a total porosity of 0.31 cm cm^{-3} in glass jars. Jars were then placed under two relative humidity levels (40 and 80%) to determine moisture fluctuations as reflected by VMC over 7 d.

Fig. 1: Type II fairy ring on 'TifEagle' bermudagrass research putting green.

All field studies included a visual turf quality (TQ) rating every 7 d throughout each study. Water droplet penetration time (WDPT), infiltration rate, volumetric soil moisture content (VWC), and soil temperature and were also assessed every 7 d for the duration of each study. Data are means of two studies repeated in time. The experimental design for each field study was a randomized complete block with three replicates and 2 x 3 meter plots. The experimental design for Objective 4 was completely randomized with four replicates.

Results

Objective 1: Fourteen days after treatment (DAT) with Hydretain and one week after the second treatment with Cascade Plus, soil moisture in the top 5.7 cm on plots receiving light and frequent irrigation was highest following Cascade Plus application (~30%) (table 1). Soil moisture levels of Hydretain-treated plots were similar to the untreated (~10%). Thirty-five DAT, the untreated control had the highest soil moisture (28%) compared to 10% for Cascade and Hydretain-treated plots after light and frequent irrigation. Cascade is classified as a straight block co-polymer surfactant which typically enhances soil water movement (vs. retention), thus, had lower soil moisture overtime (ZONTEK and KOSTKA, 2012). Soil moisture was never significantly different across treatments on plots receiving deep and infrequent irrigation. Turf quality was unaffected

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in any study by any treatment (data not shown).

Objective 2: On the bermudagrass putting green, the highest infiltration rate was found on plots treated with Primer Select (~12 cm hr^{-1}) compared to ~6 cm hr-1 on the nontreated plots or plots treated with Hydretain and Cascade Plus (table 2). Localized dry spot was highest (~18%) for nontreated, ~11% for the humectant and <3% for the wetting agent treatments. Fairy ring intensity was lowest (42-43%) for humectant and nontreated and highest (>55%) after treatment with wetting agents. Addition of the fungicide flutolanil to Primer Select did not reduce fairy ring intensity. Soil moisture values were highest for treatments receiving Primer Select (~19%) than in treatments receiving Cascade Plus or Hydretain and the untreated control. Water droplet penetration was quickest (~1.2 sec) after application of wetting agent followed by humectant (3.2 sec) and >5 sec for nontreated.

Objective 3: Treatments did not influence soil volumetric water content of a non-irrigated bermudagrass sports pitch on a native soil (data not shown).

Objective 4: Volumetric water content was higher after addition of Cascade Plus (>20%) but was not influenced by Hydretain (table 3). Soil water content was not influenced by the relative humidity of the surrounding air.

Conclusion

Overall, adding humectant did not consistently increase soil moisture retention or improve turf quality. Wetting agents lowered LDS occurrence and mitigated fairy ring symptoms. Both wetting agents increased soil volumetric water content and decreased LDS, while Primer Select also increased soil water infiltration rate. Previous reports indicate excessive rates of moisture absorbers are necessary for soil moisture retention benefit, often leading to undesirable surface heaving/unevenness (PAEBENS et al., 2010).

	Volumetric Soil Moisture Content (%)							
	Irrigation Regimes							
	Light and Frequent				Deep and Infrequent			
Treatment	**14[1]**	**21**	**28**	**35**	**14**	**21**	**28**	**35**
Nontreated	11.7b[2]	8.6a	9.3a	27.5a	9.6a	6.0a	8.8a	9.8a
Humectant	10.3b	7.4a	8.4a	10.0b	9.9a	6.3a	8.3a	9.0a
Cascade Plus[3]	30.8a	7.0a	8.5a	10.0b	8.2a	5.9a	8.4a	10.1a

1 Days after treatment.
2 Within columns means followed by the same letter are not significantly different according to Fisher's LSD (α=0.05) test.
3 Following product label recommendations, a second application was made 7 days after initial treatment.

Tab. 1: Volumetric soil moisture percentage for treatment, various days after treatment, and two irrigation regimes on a 'L-93' creeping bentgrass research putting green.

Treatment	Infiltration Rate	VWC	WDPT	LDS	Fairy Ring Intensity
	cm hr^{-1}	%	sec	%	%
Nontreated	5.3c[1]	10.6b	5.1a	17.5ab	42.7b
Humectant	5.9c	10.1b	3.2b	11.4b	42.1b
Cascade Plus[2]	6.5c	12.3b	1.4c	2.5c	77.3a
Primer + flutolanil[3]	8.8b	18.2a	1.2c	2.2c	58.0ab
Primer Select	11.7a	19.8a	1.0c	2.8c	58.0ab

1 Within columns means followed by the same letter are not significantly different according to Fisher's LSD (α=0.05) test.
2 As per product label recommendations, a sequential application was made 7 days after initial treatment.
3 Flutolanil was applied 24 hrs after the Primer application and mowing was avoided for 24 hours following application.

Tab. 2: Infiltration rate, volumetric soil moisture content (VWC), time for water droplet penetration (WDPT), localized dry spots (LDS) occurrence, and fairy ring intensity as affected by a humectant, two wetting agents and a wetting agent plus fungicide on a 'TifEagle' bermudagrass research putting green.

Treatment	Volumetric Water Content (%)[1]
Cascade Plus	20.2a[2]
Humectant	18.5b
Tap water	18.2b
Deionized Water	16.9c

1 No main effect of relative humidity level occurred, thus, means represent volumetric water content across both levels of humidity.
2 Values in columns followed by the same letter are not significantly different according to Fisher's LSD (α=0.05) test.

Tab. 3: Volumetric water content by treatment for a humectant, a soil wetting agent and different sources of water on a loamy native soil under low (40%) or high (80%) relative humidity conditions for 7 days.

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Pesticide-free management of weeds on golf courses: Current situation and future challenges

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Introduction

Environmental concerns about the use of land for golf courses have grown over the past fifty years. Specific issues include the amount of water, pesticides and fertilizers used for golf course management. These issues have led to research/knowledge collection cases on more environmentally sound practices in turf grass management (James et al., 2012)

In Denmark, the risk of pesticide contamination of groundwater/drinking water reservoirs have resulted in several restrictions on the use of pesticides in urban areas including golf courses. A voluntary agreement between the Minister of Environment and the Danish Golf Federation was signed in 2005. The goal in the agreement was a 75 % reduction in pesticide use on Danish golf courses over a 3 year period. In order to fulfil this agreement, the need for alternative control methods increased substantially (Kristoffersen et al., 2004). From 2005 to 2008 the pesticide reduction was only 37 % and in 2013 legislation was agreed and a ceiling was set on how much pesticides could be used on the different golf course elements.

Playing quality and herbicide use on fairways

There are requirements regarding playing quality on the fairways. It is primarily desirable that the fairway grass has a high shoot density, which can carry the ball. In addition, the fairway should be smooth, uniform and relatively firm, so the ball can roll smoothly after impact. Finally, the fairway should have an attractive appearance, which is equal to a smooth and lush grass cover and no flowering weeds that might interfere with the game (Jensen, 2012; Jensen and Jensen, 2012).

Fairways make up the largest area of the golf course and are generally cut short which favours weeds like *Bellis perennis, Plantago major, Poa annua, Taraxacum sp.* and *Trifolium repens* (Jensen et al., 2012). A variety of factors can affect the occurrence of weeds in turf – both fundamental factors such as soil and climate, and issues relating to turf management (Miltner et al., 2005). Weeds can impair on course quality and therefore should be controlled. For years pesticides have been the major method of weed control.

Because of the requirements for a high playing quality on fairways and because of the large area they constitute, fairways receive a significant part of the golf course's overall management efforts, including pesticides. In the Danish Golf Federations yearly green accounts for Danish golf courses, fairways contribute approximately 75 % of the total pesticide consumption. Consumption is primarily due to herbicides (DGU, 2006, 2011).

Weed control on fairways has in decades been almost exclusively based on the use of selective herbicides. There has been very little focus on the development of culture technical methods, such as a good lawn maintenance that can promote grass growth conditions as well as the grass competitiveness against weeds.

Now that pesticide legislation on golf courses has come into force, there is an increased need to develop and improve methods for pesticide-free weed control on fairways.

Overview of strategies for pesticide-free weeds control

Pesticide-free weed control in a lawn includes different strategies. The first and most important strategy is to promote grass plant density which makes the lawn more competitive against invasion of new weeds. One important aspect is to increase fertilization (Jackman and Mouat, 1972). Fertilizer promotes grass growth, and several studies have found that an increased application of fertilizer can reduce the amount of weeds in the lawn (Kopp and Guillard, 2002). When the intention is to fight weed with fertilizer it is important to find an optimal balance between increasing the competitive ability of the established turf and the increased risk of nutrient runoff and leaching.

Other pesticide-free strategies are mechanical, thermal and cultural practices that stress, harm or kill weeds (Andersen, 2000). Mechanical and thermal weed control methods available mainly for combatting weed on pavements but different methods such as grooming, harrowing etc. have been tried on turf because these methods might damage the weeds (Kristoffersen et al., 2004; Rask and Kristoffersen, 2007). A common feature of non-chemical weed control methods is that repeated treatments are required in order to achieve efficient control. In contrast, using chemicals for weed management only requires one or two treatments each year (Popay et al., 1992; Augustin et al., 2001; Reichel, 2003). Non-chemical treatments mainly affect the aboveground plant parts, whereas systemic herbicides kill the entire plant (Popay et al., 1992). Vertical cutting, tine harrowing and topdressing are maintenance methods that can enhance grass growth but the effect on weed occurrence have only been tested on a small scale and not in relation to individual weed species (Fischer and Larsen, 2002; Larsen and Fischer, 2005). In general the methods mentioned are all non-selective in relation to weed species and they can adversely affect the turf too.

A third strategy to control weeds is the prevention of seed dispersal. A fourth strategy includes the use of biological control agents such as special types of compost or bacterial or fungal substances.

Mechanical weed control

The most common management practices on golf fairways in Demark are mowing and fertilization. Less frequently fairways are vertical cut, harrowed or aerated, and on a few golf courses fairways are top-dressed and over seeded.

In the past, management practices such as vertical cutting, harrowing, aeration or top-dressing were mainly regarded as methods to regulate growth and control thatch. However, a Danish research project challenged these management methods in relation to their effect on weed control (Fisher and Larsen, 2002; Larsen and Fischer, 2005).

The mechanical methods believed to have the greatest impact on weed control are those that affect the lawn surface. Vertical cutting is designed to promote growth conditions of the grass by removing dead plant material, but also to stress the weeds by removing a part of the leaves or the inflorescences. The same effect can be achieved by using a harrow, but thatch and inflorescence are not removed to the same extent. Larsen and Fischer (2005) demonstrated that spring-tine harrowing 4-5 times a year significantly decreased weed cover and significantly increased grass cover at Furesø and Viborg golf course. The decrease in weed cover was between 1,2 % and 2,1 % and the increase in grass cover between 1,1 % and 2,6 %. When choosing the treatment intensity it is important to know the optimal balance where weeds are inhibited without disturbing grass growth.

The experiments by FISHER and LARSEN (2002) investigated the optimal treatment frequency and treatment combination. Vertical cutting, various types of harrowing, fertilizer amount, top dressing and other management factors were evaluated in various combinations. These trials demonstrated that the effects on weed occurrence were mostly small and the overall reduction in weeds on football pitches and golf course fairways was not significant.

The poor efficacy of mechanical weed control methods in FISHER and LARSEN (2002)'s experiments calls for a more differentiated approach towards pesticide-free weed control. We believe that the way forward is to refine methods that can be used on small areas depending on the target weed species. In order to get ideas for the optimal weed control strategy for the individual species we need to evaluate the practical experiences on golf courses. In the following experiences from practical trials initiated by greenkeepers are presented and discussed in relation to using them in a differentiated pesticide-free weed control approach.

Weed burning

In Denmark a number of experiments on burning weeds on pavements have been carried out (Kristoffersen et al., 2008; Rask et al., 2012). Sensitive weed species responded to a dose between 10 and 150 kg gas per hectare, and 95 % control of sensitive species such as *Chenopodium album* was obtained. Plants with a protected apical meristem such as the grasses needed a higher dose in order to be controlled (Ascard, 1995, 1998). Therefore burning might be effective in removing some problematic weed species from a smaller lawn area without eliminating the grass plants. Some injury on the leaves can be expected, but the grass will be able to overcome these injuries because the growth meristem is protected and close to the ground (RASK and KRISTOFFERSEN, 2007)

In a small burning experiment at the driving range at Furesø golf course (Copenhagen) in 2010-2011 (burning 2 times in fall and 2 times in spring) *Bellis perennis* responded to a gas dose of 80 kg per ha (Table 1). Two weed species, *Taraxacum sp.* and *Trifolium repens*, did not respond to flaming. After burning the turf showed injuries, between 5-40 % – depending on the gas dose but recovered after 2-4 weeks. For *Cerastium fontanun* there was an increase from fall to the next spring but burning provided control compared to the non-treated.

This small experiment indicate that some weed species might be sensible to a burning treatment and that weed control using a weed burner might be a solution in small restricted turf areas. The next step is to perform an experiment for a longer period on a larger scale for multiple weed species.

Stripping off old and weedy turf followed by resowing

Some weed species have a very superficial root growth whereas others have a tap root. Stripping off turf followed by resowing might be a method to reduce the number of superficially rooted weed species and the seed bank of certain weeds in the soil. At the same time, the botanical composition can be changed in favour of more competitive or durable grass species/varieties.

Stripping off the turf has been used earlier when renovating greens (Mortensen et al., 2005). One of the advantages is that stripping off the top 2-3 cm removes most of the seed bank of annual meadow-grass (*Poa annua*) which can be more than 150000 seeds per m^2 (Lush, 1988). A Norwegian study investigating various methods for renovation of greens after winter-kill documented that stripping off the turf followed by resowing of a mixture of red fescue (*Festuca rubra*) and brown top bent (*Agrostis capillaris*) resulted in a botanical composition of 99 % fescue/bent and only 1 % annual meadow-grass as opposed to 48 % fescue/bent and 52 % annual meadow-grass in the control treatment where the seed mixture was drilled directly without stripping (Kvalbein, 2009).

The greenkeeper at Furesø Golf Course (Copenhagen) tried stripping plus resowing as a means to reduce weed occurrence and change the botanical composition on fairway in favour of red fescue (*Festuca rubra*). His experience was that stripping off the old turf removed *Cerastium fontanum* as these weeds did not appear the year after. However weed species with taproots, such as *Taraxacum sp.* and *Plantago sp.* were not removed. They reappeared quickly in the new turf.

Stripping is very expensive. The estimate from Furesø GC was that it took 4-5 hours to strip 800 m^2. Therefore stripping is not a solution on large areas. However it might be a solution for weed management in small areas depending on the type of weed.

Grazing

For many years grazing has been used for landscape management (Hadjigeorgiou et al., 2005). Some animal species are very effective in grazing/eating weeds (Popay and Roger, 1996). A number of golf courses in Denmark and Sweden are now using animals for weed control.

Species	Change in control treatment (%)	Change in flaming treatment (%)
Taraxacum sp.	-0,31	-0,43
Trifolium repens	-4,25	-4,07
Bellis perennis	-0,79	-2,07
Medicago sativa	0,85	0
Cerastium fontanum	2,61	1,10

Tab. 1: Change in per cent coverage of weeds from fall 2010 to spring 2011 in a burning experiment at Furesø GC, Copenhagen (80 kg gas per ha).

On Hørsholm Golf Course north of Copenhagen grazing was originally established on a part of the course where the sheep had access to all of the golf course elements (greens, tees, fairway and rough). Before grazing was initiated the establishment of clover (*Trifolium repens*), poplar (*Populus sp.*) and the black-list species giant hogweed (*Heracleum mantegazzianum*) was a major problem. The introduction of sheep on the golf course helped to alleviate these problems. This effect on giant hogweed was also observed at Smørum Golf Course (Copenhagen) where the animal ate the seedlings before the inflorescences were produced. At Hornbæk Golf Course (North Zealand) three years of grazing have demonstrated that sheep were efficient in preventing willows (*Salix sp.*) and birches (*Betula sp.*) from getting establishment (Jensen and Edman, 2011).

Besides controlling weeds, grazing will also change the character of the rough. By eating many of the large and competitive grass species, sheep create an open rough with fine grasses and a better playing quality because the players are able to find the golf ball.

However there was one main problem with the grazing regime at Hørsholm. The sheep were lying on the greens at night and their urine caused scorched spots on the greens. That was not acceptable and today the greenkeepers keep the sheep in mobile enclosures mainly in the rough areas.

Specific equipment for weed control/management

Some greenkeepers have tried to develop or modify mechanical equipment to achieve better control of target weed species.

At Värpinge Golf Course Sweden, a modified vertical cutting aggregate for a Toro 5610 was tested to control dandelions (*Taraxacum sp.*). Blades were mounted at a distance of 2.5 cm. The blades did not go into the topsoil/ but operated at a height approximately 1 cm above ground and disrupted the leaves of the dandelions. This treatment did not remove the dandelion but the plants became smaller and the negative effect on the playing quality was diminished. This example shows that investigations into weed control on fairways should not only focus on how to kill the weeds, but also on how to manage them in order to minimise the negative effect on playing quality.

Overseeding and topdressing

Overseeding has not been a common maintenance procedure on Danish golf fairways. However, the introduction of new plants with higher shoot density will usually result in less space for the establishment and growth of weeds (Morris, 2004; McCarthy, 2009). Overseeding might therefore have a long term effect on weed occurrence.

The experiments by Fisher and Larsen in 1999-2001 showed conflicting results of overseeding plus topdressing depending on seeding rate, seeding time and soil fertility levels (Larsen and Fischer 2005). A clear positive effect on weed occurrence after two years was seen at Viborg GC (Jutland), and this effect was still visible ten years later (Nyholt, 2010).

At the moment a research project is ongoing in Denmark and Norway investigating the effect of different overseeding procedures on weed occurrence.

Earthworm castings and weed establishment

A major problem on many golf courses is the creation of earthworm casts on fairways, tees and sometimes even on greens (Collins et al., 1995; Williamson, 2004; Potter et al., 2013). Especially in autumn, there may be many worm casts. These casts are smeared by the machines used for maintenance and they become perfect niches for weed establishment. In particular annual meadow grass (*Poa annua*) will be promoted by these casts due to its ability to germinate almost all year around.

The head greenkeeper at Furesø Golf Course performed a number of small experiments in order to find a method for reducing earthworm casts on fairways with clay soils. He found applications of sand mixed with an acid fertilizer reduced the pH and moisture in the top soil. His experience was that not only the number, but also the structure of the casts changed, thus allowing less annual meadow grass and other weeds to germinate. His findings are in agreement with GUILD (2008) and POTTER et al. (2013) showing that the upward and downward movements of earthworms in the soil are influenced by soil moisture and soil temperature, and that earthworms are sensitive to acidic soil conditions.

Future directions

The future calls for a reduction in herbicide use in turf due to legislation and volunteer agreements. Danish experiments and practical experiences on pesticide-free control demonstrated that so far we have no universal or selective methods that can effectively eliminate weeds on golf courses.

Weed species respond differentially to mechanical treatments and the timing and frequency of specific mechanical treatments also have a strong impact. Therefore the approach regarding mechanical weed control needs to be changed. More knowledge of the individual weeds' morphology, physiology and demography under turf conditions is needed to find effective mechanical weed control methods. Understanding the various growth stages where the weed species may be most vulnerable to mechanical damage is particularly important (Nkurunziza et al., 2011).

The indications that burning might have an impact on some weed species without harming the grass plants and that stripping can remove the seed bank and eliminate weed species with a superficial root system should encourage a more profound investigation of these methods in relation to weed control. These methods might be reasonable to use in small areas with severe weed problems. We must also to a larger extent establish thresholds for the individual species in order to decide when a specific treatment is justified to improve the functional quality of the turf.

From an economic perspective, there is no doubt that pesticide free management is more time consuming and expensive than chemical control, and this is likely to influence the willingness of turf managers to choose non-pesticide options in a time with increasing economic pressure on many golf clubs. Furthermore, if aspects such as fossil fuel consumption and CO_2 emissions are included, it remains to be documented if managing turf weeds totally without herbicides is more economically and environmentally sustainable than management with a minimum input of herbicides according to IPM principles. However, by targeting non-chemical methods to the biology and weaknesses of the individual weed species under turf conditions, it should be possible to reduce the golf courses' dependence on herbicides for weed control.

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The effect of ice encasement and two protective covers on the winter survival of six turfgrasses on putting greens

Waalen, W.M., T. Espevig, A. Kvalbein and T.S. Aamlid

Introduction

Winter damage on putting greens is a significant economic burden for golf courses at northern latitudes. Approximately 70 % of Scandinavian golf courses suffer from winter damage with approximate losses of SEK 300.000 every year (KVALBEIN et al. 2013). During the winter, plants are subjected to a multitude of stresses, which differ from region to region and from year to year. Grass plants may have to tolerate one or a combination of the following stress factors: i) lack of light; ii) prolonged exposure to freezing temperatures; iii) flooding or ice encasement (IE); iv) fungal diseases; v) soil heaving; vi) solar radiation and vii) wind. Winter stress management options with the aim to minimize winter stress injuries are required. Protective covers against low temperatures and IE have been utilized in Canada with promising results (ROCHETTE et al., 2006; ASHER et al., 2009; TOMPKINS et al., 2009). Ice encasement issues are one of the most important winter stress factors in Scandinavia, however little is known about the IE tolerance of the different putting green species/sub species. A number of Scandinavian golf courses have started using protective covers and it was therefore of interest to further study the response of protective covers under Scandinavian conditions.

Objective

The objective of this study was to assess the impact of IE and two protective covers on the winter survival of the most common turfgrass species in Scandinavia.

Materials and Methods

The experiment was conducted on a USGA-green seeded with colonial bentgrass (*Agrostis capillaris*), velvet bentgrass (*A. canina*), creeping bentgrass (*A. stolonifera*), Chewings fescue (*Festuca rubra ssp. commutata*), slender creeping red fescue (*F. rubra ssp. trichophylla*) and annual bluegrass (*Poa annua*) at the Bioforsk Research Station, Apelsvoll, Norway, 61°41′ N (inland climate), during the winters of 2011-12 and 2012-13. The green was seeded in mid-June of 2011 and 2012 due to destructive sampling throughout the experiment. Nitrogen was applied from May to September at two-week intervals which amounted to 2 kg m^{-2} $year^{-1}$ for *Festuca spp.*, 2.8 kg m^{-2} $year^{-1}$ for *A. canina* and *A. capillaris*, and 3.2 kg m^{-2} $year^{-1}$ for *A. stolonifera* and *P. annua* (ERICSSON et al., 2012). One fungicide application of Delaro® (prothioconazole and trifloxystrobin) was applied during late September at a rate of 1L ha^{-1}. The two protective covers (plastic and plastic covering a 10 mm woven mat to create an air space underneath) were installed in November once the ground was frozen. IE was established on 22.11.11 and 4.12.12 after the soil surface was frozen by adding small amounts of water over a period of three days. The control treatment consisted of natural winter conditions. Core samples (8 cm diameter) were removed from the plots at the time of cover installation, and then 6 times with two-week intervals from the start of January until snow melt. Core samples were thawed for two days at 4 °C, clipped to 4 mm, potted and set to grow in a growth chamber under optimal conditions (18 °C day/night temperature, 18-h photoperiod) for 21 d. At this point percentage turf coverage was determined. The percentage of turf coverage was also determined on field plots on 22.03.12, 25.04.12 and 29.05 and 06.05.13 and 27.05.13. These are reported as average coverage for each of the experimental years. The experiment was a split-split-plot design, with covers as the whole plot treatment, and turfgrass species and date of sampling as the sub-plot treatments.

Results and Discussion

The first winter was short, with warmer temperatures and an earlier snow melt than normal. Mild temperatures beginning in January caused a layer of ice to accumulate under the snow over all treatments. The second winter of the experiment was a more normal winter, with 141 days of snow cover and no ice development observed under the snow on control plots.

The plastic cover and plastic with a mat improved the coverage of *P. annua* in

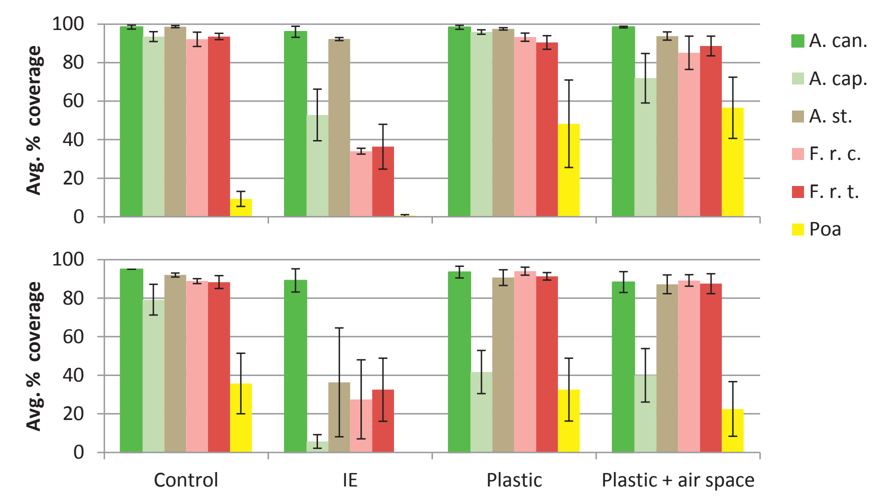

Fig. 1: The effect of natural snow cover, IE, plastic cover and plastic cover with a mat on the average percentage coverage of *A. canina* (green), *A. capillaris (light green), A. stolonifera (brown), F. rubra ssp commutata (pink), F. rubra ssp. trichophylla (red)* and *P. annua* (yellow) in the spring of 2012 (a.) and 2013 (b). Bars indicate standard errors of the means (SE).

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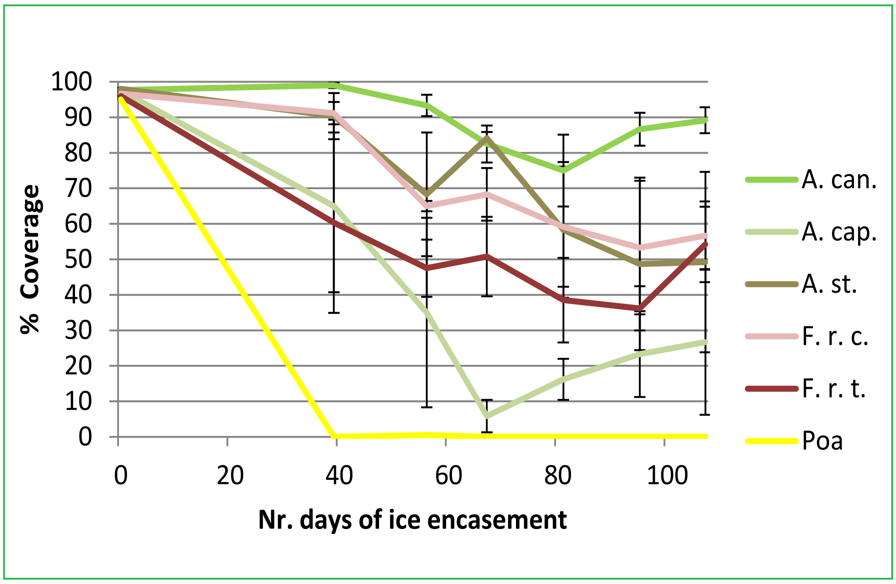

Fig. 2: The effect of duration of IE on percent coverage of *A. canina* (green), *A. capillaris (light green), A. stolonifera (brown), Festuca rubra ssp commutata (pink), F. rubra ssp. trichophylla (red)* and *Poa annua (yellow)* registered after the removal of IE and 21 d. of regrowth during the winter of 2012/13. Bars indicate standard errors of the means (SE).

the spring of 2012, but no benefits of the covers were measured in the spring of 2013 compared with control and IE (Fig.1). The response in 2012 was most likely due to the avoidance of complete IE under the covers. The springtime coverage of *A. canina, A. stolonifera, F. rubra ssp commutata* and *F. rubra ssp. trichophylla* had no response to the covers, compared with natural winter conditions in both years. In the spring of 2012, *A. capillaris* which had been covered with plastic with a mat had poorer springtime coverage, compared to natural winter conditions and the plastic cover. In the spring of 2013 the turf coverage of *A. capillaris* was negatively affected by both protective covers compared to natural winter conditions. This was probably due to the development of *Microdocium nivale.*

Figures 1a and b show that the spring coverage of *A. canina* was not significantly reduced by the IE conditions after 98 or 119 d in 2011/12 and 2012/13, respectively. In the spring of 2012 the coverage of *A. stolonifera* was also not reduced by IE. This was however not the case in 2013, indicating that *A. canina* has better tolerance to longer IE conditions, compared to *A. stolonifera*. The coverage of *P. annua* was reduced by 50% after only 20 d of IE (Fig. 2). The tolerance of *A. capillaris* was also poor, with coverage dropping to 50% after approximately 50 d. *A. canina* on the other hand showed superior tolerance to IE, and even after 119 d of IE the coverage had not dropped to below 75%.

Conclusions

Results indicated that velvet bentgrass had superior tolerance to IE lasting for 98 and 119 d in 2011-12 and 2012-13, compared to the five other species/subspecies. IE conditions did not significantly impact the coverage of *A. canina* in the spring, compared to natural winter conditions. *A. capillaris* responded negatively to the protective covers. *P. annua* was shown to have the lowest tolerance to IE and it was the only species which benefited from the protective covers.

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Establishment and winter management of 'MiniVerde' bermudagrass for putting greens in Italy

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Introduction

Many areas of the Mediterranean climate combine mild winters with drought and high temperatures during summer, representing a transition zone for turfgrasses (DUNN AND DIESBURG, 2004). While hybrid and seeded bermuda-grass cultivars are currently adopted on golf fairways in Italy, the use of dwarf cultivars of *Cynodon* on greens still needs to be accepted. A major obstacle for their diffusion in Italy is the lack of information on their establishment, playing quality and winter management. As to winter management and playing quality, previous research carried out in Italy (VOLTERRANI et al., 2009) indicated that *Lolium perenne* and *Festuca rubra* are suitable for winter overseeding nonetheless the best playing quality (green speed) was recorded on the non overseeded surface. This means that dormant bermudagrass greens could be acceptable for use during winter assumed the lack of green colour is tolerated. In other countries turf painting is becoming increasingly popular for winter management of dormant putting greens (BRISCOE et al., 2010). With the aim of facilitating the use of dwarf bermudagrass in Italy, this trial had the object to monitor the establishment of 'Miniverde' bermudagrass at three different latitudes and to assess at the northern one whether the application of turf paint could provide an acceptable green color of the dormant turf.

Materials and Methods

Sprigs of hybrid bermudagrass *Cynodon dactylon x C. transvaalensis* cv. 'MiniVerde' were raised in the green house in peat-filled seed trays with plugs of 5 cm^3. Subsequently, plants were manually transplanted at a density of 30 plants m^{-2} on mid July 2012 in three different Italian locations: Montecchia Golf Course, in Padova (45°24' N, 11°52′ E), Golf Village Golf club, in Porto Recanati (Macerata) (43°25′ N, 13°39′ E) and Le Costiere Persano Royal Golf, in Serre (Salerno) (40°34' N, 15°08′ E). In each location four 50 m^2 plots were set up. Water was applied as needed to encourage establishment. Diammonium phosphate was applied at planting at 20 g m^{-2} rate. Top dressing fertilization was carried out from July to September with 10 g m^{-2} of urea per week and 10 g m^{-2} of potassium sulphate every other week. During establishment plants were left unmown. Mowing was started from August 2012 and cutting height gradually brought to 4 mm. Weeds were manually removed where necessary. In order to monitor establishment, every ten days from 31 July to 20 September digital images of plots were taken and processed by digital image analysis to determine the percent of green ground cover. Data were subject to statistical analysis and standard error was calculated for mean comparison.

Following full establishment, a turf painting trial was carried out at the northern location (Padova) where the bermudagrass was expected to undergo the most prolonged dormant period. The product Green Lawnger was applied at 4.1 L ha^{-1} and 12.3 L ha^{-1} application rates of pure colorant in a mix having a 1:7 colorant:water ratio. An untreated control was included as a reference. Treatments were arranged in a randomized complete block experimental design with three replications. Plot size was 13 m^2.

In order to determine colour persistence, green colour was visually assessed from 1 November 2012 to 13 April 2013 on a 1 to 9 scale (1 = brown turf, 5 = acceptable green, 9 = dark green). In three occasions during the bermudagrass dormant period, colour dropped below the acceptable value of 5 in some of the plots. In order to restore an acceptable colour treatments were repeated for all plots on 2 and 26 November 2012 and 4 February 2013.

Core samples with a 86.4 cm^2 surface area and 15 cm depth were collected on 19 April and 17 October 2013 in order to detect any effects of painting treatments on turf characteristics at spring green up and at the end of the following growing season. Shoot density, root dry biomass, stolon dry biomass and stolon density were measured. On 4 January 2013 in Padova location, green speed was determined by stimpmeter readings. Data were subject to ANOVA and Least Significant Difference calculated for P≤0.05 level.

Results

Despite the expectations based on latitude of the three locations included in the trial, on 20 September 2012 full ground cover was reached in Salerno and Padova while in the Recanati location a slight delay in establishment was observed (Table 1).

Winter colour management with the use of turf painting provided a good colour during the dormant period of 'MiniVerde' bermudagrass assumed

Location	31 Jul.	1 Aug.	11 Aug.	21 Aug.	1 Sept.	11 Sept.	20 Sept.
	Green ground cover (%)						
Padova	5 (±0.1)	12 (±2.6)	37 (±3.6)	58 (±4.1)	76 (±3.1)	85 (±3.5)	95 (±2.9)
Recanati	5 (±0.1)	9 (±3.1)	23 (±3.5)	42 (±4.2)	61 (±4.0)	75 (±4.1)	86 (±3.1)
Salerno	5 (±0.2)	21 (±3.5)	43 (±4.1)	64 (±3.8)	80 (±4.0)	90 (±3.9)	98 (±1.1)

Tab. 1: Green ground cover during establishment of MiniVerde bermudagrass in three locations in Italy. Standard error is reported in brackets.

Pure colorant application rate (L ha^{-1})	1 Nov. 2012	2 Nov. 2012[1]	25 Nov. 2012	26 Nov. 2012[1]	4 Feb. 2013	5 Feb. 2013[1]	12 Apr. 2013
No paint	4	4	2.5	2.5	1	1	2.5
4.1	4	5.5	4.5	5	4.5	6.0	4.5
12.3	4	7.5	6.5	8.0	6.5	8.0	6.5
LSD (0.05)	-	*1.0*	*1.3*	*1.2*	*1.0*	*1.5*	*1.5*

[1] Assessment made after paint application

Tab. 2: Winter color of dormant and painted turf of MiniVerde bermudagrass in Padova (1 = brown turf, 5 = acceptable green, 9 = dark green).

Pure colorant application rate (L ha^{-1})	Shoot density (n° cm^{-2})	Root dry biomass (mg cm^{-2})	Stolon dry biomass (mg cm^{-2})	Stolon density (cm cm^{-2})
No paint	4.4	6.0	37.2	6.2
4.1	5.7	6.5	38.2	6.8
12.3	7.8	7.3	41.7	7.5
LSD (0.05)	*0.6*	*0.4*	*0.8*	*0.3*

Tab. 3: Effect of turf painting on shoot density, root and stolon specific biomass and stolon density of Miniverde bermudagrass in Padova (19 April 2013).

that multiple applications were carried out with the highest application rate and every time that the exposure to atmospheric factors causes a decline in colour (Table 2).

Winter application of painting significantly affected turf characteristics at spring green up. Increases in turf density, root and stolon specific biomass as well as stolon length were observed in comparison with the non treated control, the most marked effects being associated with the higher application rate (Table 3). On 17 October 2013, none of those differences were significant and untreated plots had similar turf characteristics compared to plots treated with high and low rates of painting (data not shown).

As expected, the dormant turf provided good playing conditions and the application of turf painting did not affect this characteristic of the putting surface. Stimpmeter readings did not detect significant differences in green speed between treated and control plots with a mean value of 2.6 m being recorded.

Acknowledgments

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Nitrate leaching from establishing bermudagrass irrigated with treated effluent

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Introduction

Treated effluent (also called recycled or reused) water has become an important source of irrigation water for turfgrass. Newly developed decentralized water treatment systems can produce recycled water containing varying quantities of N on short notice. Using such effluent water to irrigate turf areas would reduce or eliminate the need for additional mineral fertilizers if concentrations of nitrate in the water were raised above the current legal limit for treated effluent during the growing season to meet the annual N requirement (SEVOSTIANOVA and LEINAUER, under review). Irrigation water containing concentrations of nitrate that vary over a growing season has been defined as tailored water. There is, however, concern that excessive concentrations of nutrients in recycled water could result in surface and groundwater contamination. The potential contamination of groundwater due to N fertilization of turfgrasses has been intensively studied, but little is known about nitrate leaching from turf areas irrigated with treated effluent. Information is also scarce on N-leaching from turfgrass rootzones during establishment. GERON et al. (1993) investigated the effect of different fertilization on turfgrass establishment and nitrate leaching and found differences in NO_3-N leachate between seeded and sodded cool-season Kentucky bluegrass (*Poa pratensis* L.). Similar studies have not been conducted to determine if nitrate leaching differs between seed and sod-established turfgrass when irrigated with treated effluent. Generally, propagating turfgrasses from seed is cheaper, but establishment is slower than propagation from sod, and the risk of nitrate leaching from seeded turf could be greater than from sodded turf. A study was conducted at New Mexico State University to investigate the effects of treated effluent water seasonally adjusted for NO_3-N content (tailored water) on the establishment of bermudagrass (*Cynodon dactylon* (L.) cv. 'Princess 77') propagated from seed or sod, and on salt and nitrate leaching from the turfgrass rootzone.

Materials and Methods

A greenhouse study was conducted during summer of 2013 using tailored water to fertilize 'Princess 77' bermudagrass during establishment from seed and sod. Twelve containers, 30 cm in diameter and 60 cm in height and filled with a local Bluepoint loamy sandy soil. Suction lysimeters were inserted at depths of 10 and 20 cm and leachate from below the rootzone was collected as drainage water exiting the bottom of the cylinders. Containers were either seeded at a rate of 10 g m^{-2} pure live seed or propagated the same day of planting. Irrigation was applied daily at 100% of reference evapotranspiration (ET_0) with either tailored or potable water. Tailored water had an electrical conductivity (EC) of 2.3 dS m^{-1} and contained 15 ppm NO_3-N. Pots irrigated with potable water were fertilized with granular calcium nitrate every other week at a rate of 1.5 g N m^{-2} to match the total N applied to containers irrigated with tailored water. Leachate was collected bi-weekly and analyzed for NO_3-N and EC. Percent green coverage in each container was determined by means of digital image analysis (Sigma Scan Pro, Systat Software 132 Inc., San Jose, CA) from photographs taken weekly. The experimental design was completely randomized with three replications per treatment. All data were subjected to analysis of variance (ANOVA) using SAS Proc Mixed followed by multiple comparisons of means using Fisher's protected least significant difference test at the 0.05 probability level.

Results

Leachate

The Statistical analysis revealed a significant three-way interaction effect between sampling depth, sampling date, and type of propagation on NO_3-N content in the leachate. Analysis of variance also revealed that NO_3-N concentration and EC of leachate was significantly affected by three way interactions between water quality, sampling date, and propagation.

Generally, the highest NO_3-N concentrations at all depths were recorded on June 20, one week after propagation (Table 1). At that point in time roots had not developed and plants were unable to take up NO_3-N from the soil solution. When data were averaged over all depths, bermudagrass propagated from sod exhibited highest concentrations of NO_3-N in the leachate and 'Princess 77' established from seed the lowest (Figure 1). Nitrate-N content in the leachate declined steadily until the end of the research period for all treatments. From July 6, three weeks after establishment onwards, nitrate concentrations in the leachate dropped below the EPA threshold for drinking water in all grasses, regardless of propagation type or quality of irrigation water (Table 1, Figure 1).

On three of the four sampling dates (July 6 to August 8) leachate EC was higher in rootzones of bermudagrass irrigated with tailored water than with potable water (Figure 2). Moreover, leachate EC in turf established from seed and irrigated with tailored water was higher than in turf propagated from sod (Figure 2). There was no difference in leachate EC between the two propagation types in turf irrigated with potable water (Figure 2). Leachate EC in rootzones of 'Princess 77' established from seed was higher than in 'Princess 77' established from sod (Figure 2).

Percent green coverage

'Princess 77' irrigated with tailored water established faster than 'Princess 77' irrigated with potable water and reached full coverage approximately 6 weeks after seeding. Percent green coverage was consistently higher in turf irrigated with tailored water for all sampling dates (Figure 3).

	10 cm	20 cm	Drainage
June 20			
Seed	25.65B†	30.74B	26.07B
Sod	23.72B	26.0B	88.11A
July 6			
Seed	9.16C	3.73CD	2.37CD
Sod	1.16D	0.4D	0.44D
July 20			
Seed	0.15D	0.62D	2.70CD
Sod	0.26D	0.38D	0.16D
August 8			
Seed	0.10D	0.06D	0.23D
Sod	0.41D	0.11D	0.10D

† Values followed by the same letter are not significantly different from one another (Fisher's protected LSD, α = 0.05).

Tab. 1: NO_3-N (mg L^{-1}) in soil leachate for seeded and sodded bermudagrass at two soil depths and in the drainage water. Data are pooled over water quality (potable and tailored) and represent an average of six samples (two water qualities and three replicates).

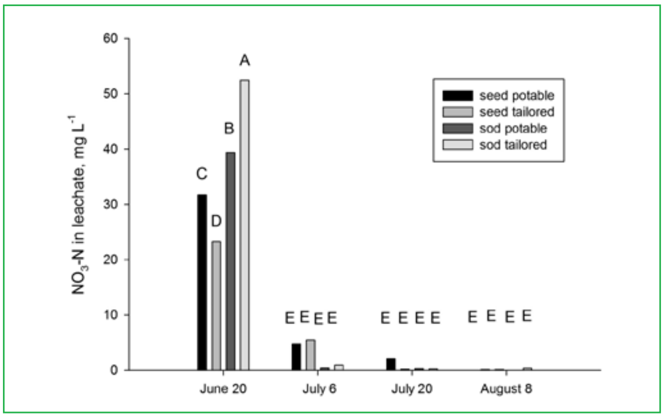

Fig. 1: Changes in nitrate-N content in the leachate of 'Princess 77' bermudagrass propagated on June 15 from either seed or sod and irrigated with either potable or tailored (treated effluent with 15 ppm NO_3-N) water. Data are averaged over 3 sampling depths. Bars with the same letters are not significantly different from one another (Fisher's protected LSD at $\alpha = 0.05$).

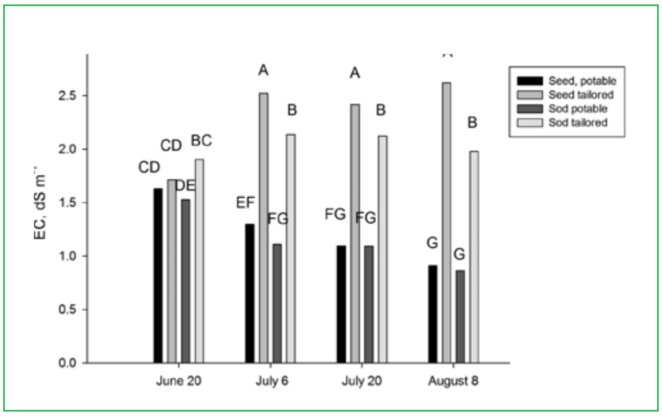

Fig. 2: Changes in leachate electrical conductivity (EC) of 'Princess 77' bermudagrass propagated on June 15 from either seed or sod and irrigated with either potable or tailored (treated effluent with 15 ppm NO_3-N) water. Data are averaged over 3 sampling depths. Bars with the same letters are not significantly different from one another (Fisher's protected LSD at $\alpha = 0.05$).

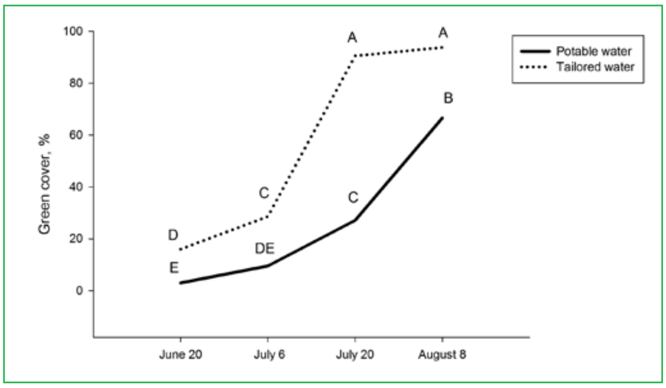

Fig. 3: Changes in percent green cover of 'Princess 77' bermudagrass propagated on June 15 from seed and irrigated with either potable or tailored (treated effluent with 15 ppm NO_3-N) water. Data points with the same letters are not significantly different from one another (Fisher's protected LSD at $\alpha = 0.05$).

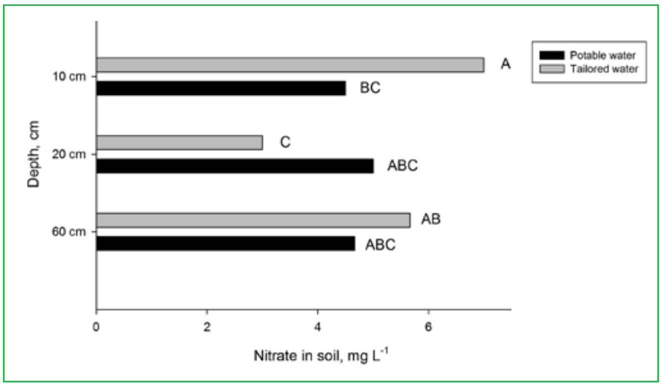

Fig. 4: Soil nitrate-N levels at 3 sampling depths under 'Princess 77' bermudagrass established with either potable or tailored (treated effluent with 15 ppm NO_3-N) water. Data are averaged over 2 propagation types (seed and sod). Bars followed by the same letters are not significantly different from one another (Fisher's protected LSD at $\alpha = 0.05$)

Soil

The ANOVA of nitrate content in the soil revealed a significant two-way interaction between water quality and soil depth. At the end of the research period, nitrate concentrations were highest in containers irrigated with tailored water at the depths of 10 cm and in the drainage water (Figure 4). No differences in soil concentrations of NO_3-N between depths were observed in treatments irrigated with potable water (Figure 4).

Discussion and Conclusions

The amount of NO_3-N in the leachate decreased steadily in both seeded and sodded grasses as the root systems developed. These results support those of EVANYLO et al. (2010), who documented a high nitrogen assimilation capacity of bermudagrass, which prevents significant leaching of nitrogen. Our study found that nitrate concentrations in leachate did not differ between sodded and seeded bermudagrass. This differs from what was observed by GERON et al. (1993), who reported that seeded plots of Kentucky bluegrass developed less root mass during first 2 months of study than sodded plots, resulting in more nitrate leaching. Although EC of the leachate was higher in the containers irrigated with tailored water, percent green coverage was not affected by this increase in salinity. On the contrary, bermudagrass irrigated with tailored water consistently exhibited greater green coverage. These results support those of DUNCAN et al. (2009), who reported a high salinity tolerance of bermudagrass. Our results indicate that establishing bermudagrass using tailored water at 15 ppm NO_3-N produces no more nitrate in the leachate as a combination of potable irrigation water and granular fertilizer.

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Effect of turf species on pesticide clipping concentrations and subsequent release in aquatic systems

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Introduction

Clipping management is a topic within the turf industry that has gained notable attention in recent decades. Previous research has shown herbicide residues within clippings from previously-treated turf may become bioavailable as they decompose, potentially causing adverse effects on terrestrial and aquatic plant growth (BEZDIEK et al. 2001; LEWIS et al. 2013). With the use of radio-labelled compounds, plant uptake and metabolism experiments have proven grass species with relatively similar growth characteristics can metabolize herbicides at different rates (MCCULLOUGH et al. 2009). Under certain conditions, clipping displacement may occur. Field research was conducted to quantify pesticide residues in clippings from various turf species. A subsequent controlled-environment experiment was conducted to measure pesticide release from clippings into water. Information from this research may improve best management practices with regards to turf selection, pesticide application scheduling, and post-application irrigation and mowing practices.

Materials and Methods

Field research was conducted (Lake Wheeler Turf Field Lab, Raleigh, NC, USA) to quantify pesticide residues in clippings from three turf species collected at varying times after application. Turf species included hybrid bermudagrass (*Cynodon dactylon* (L.) Pers. × *Cynodon transvaalensis* Burtt-Davey, cv. 'Tifway 419'), tall fescue (*Lolium arundinaceum* (Schreb.) syn. Festuca arundinacea S.J. Darbyshire 'Kentucky 31'), and zoysiagrass (*Zoysia japonica* Steud. 'El Toro') maintained at 5, 9, and 5 cm, respectively. In short, 2,4-D, azoxystrobin, and imidacloprid were applied at 1.5, 0.5, or 0.6 kg ai ha^{-1}, respectively, to unique 1.2 m x 3 m plots (1.5 m alley between blocks) at 32, 16, 8, 4, 2, 1, or 0 days before clipping collection (DBCC). Treatments were made with a CO_2-pressurized, three-nozzle boom calibrated to deliver 812 L ha^{-1}. From 32 to 4 DBCC, clippings were returned to all plots with a self-propelled rotary mower. The mower was washed and dried between mowing in treated plots. At 0 DBCC, pesticide treatments were applied and allowed to dry for 2 hours before clipping collection occurred. Clippings were collected from each experimental unit in a plastic-lined self-propelled rotary mower bag, homogenized, and subsampled to determine pesticide concentrations with HPLC-DAD methods. The bulk sample was then stored at -14 °C.

Following turf clipping collection, a controlled-environment experiment was conducted to evaluate pesticide release from previously-treated turf clippings over time. Water was collected from a local source (Raleigh, NC, USA) with nondetectable 2,4-D, azoxystrobin, and imidacloprid concentrations. At experiment initiation, 40 g clippings were mixed with 400 mL water in unique polyethylene containers (946 cm^3) and sealed. Containers were stored in the dark at 25 °C, opened (30 min) and hand-shaken daily. Water samples (20 mL) were collected 0, 1, 2, 4, 8, 16, and 32 days after clippings application to water (DACAW) and pesticide concentrations were determined with HPLC-DAD methods.

Experiments evaluated three replications of a 3 by 3 factorial treatment arrangement in a randomized complete block design. Factorial levels included three turf species (hybrid bermudagrass, tall fescue, or zoysiagrass) and three pesticides (2,4-D, azoxystrobin, or imidacloprid). Turf clipping pesticide concentrations were converted to a per cent of the original field application, while pesticide release in water was converted to a per cent released from the total within clippings. Data were then subjected to ANOVA ($P = 0.05$), with pesticide and turf species considered fixed effects. Means were separated according to Fisher's protected LSD ($P < 0.05$) with the use of SAS general linear models.

Results

Pesticide-clipping residue data analysis determined a pesticide by turf species interaction at all clipping collection dates. Overall, bermudagrass (2-42%) clippings had equal to or more pesticide residues than tall fescue (0-33%) or zoysiagrass (0-27%). Further, residues in zoysiagrass were less than tall fescue at most clipping collection dates. Differences between species suggests uptake, translocation, and metabolism may vary, which may make certain turf species less likely to transport pesticides away from the intended site via clipping displacement. 2,4-D concentrations were greatest for clippings that were collected from 0 to 2 DBCC (42-17% of the applied), while azoxystrobin concentrations were greatest from 4 to 16 DBCC (10-2% of the applied). Imidacloprid concentrations were consistently equal to or less than 2,4-D and azoxystrobin. Pesticide concentrations in turf clippings declined from 0 to 32 DBCC, with < 2.5% of the applied detected for 2,4-D (bermuda and tall fescue) at 32 DBCC.

In general, maximum pesticide release from clippings occurred at the 2 DACAW and declined over time for all pesticides. Overall, pesticides released into water from clippings consistently across turf species. Pooled over species, pesticide release was compound-specific. Despite it being the least concentrated in turf clippings, imidacloprid was the most readily released, followed by 2,4-D and azoxystrobin. This may be attributed to differential pesticide uptake and metabolism between compounds. Further, differing chemical properties between pesticides likely influences release from plant tissue into an aqueous environment. At 2 DACAW, 2,4-D release from turf clippings averaged 46, 54, and 55% from clippings collected 2, 4, and 8 DBCC. Based off this data, clipping management practices in 2,4-D treated turf areas need to account for the potential of this compound to release into surface water bodies, as it has been previously documented to adversely effect aquatic flora growth and overall ecosystem health.

Conclusions

Data suggest pesticide residues in turf clippings and subsequent release into aqueous systems is both pesticide- and species-dependent. Overall, pesticide residue in turf species ranked bermudagrass > tall fescue > zoysiagrass; while pesticides ranked 2,4-D > azoxystrobin > imidacloprid. In general, pesticide release from turf clippings was not species-dependent; however, across turf species, pesticide release ranked imidacloprid > 2,4-D > azoxystrobin. This research will improve our knowledge of clipping management practices following applications of three commonly applied pesticides to three turf species widely utilized throughout the United States. By doing so, best management practices may be developed to avoid off-target environmental impacts associated with pesticide residues in turf clippings. Future research should evaluate alternative application techniques and post-application irrigation management to reduce pesticide concentrations in turf clippings.

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Mapping golf courses for multifunctional uses other than g olf

Caspersen O.H, A.D. Jensen and F.S. Jensen

Introduction

In Scandinavia there is an increasing interest for multifunctional use of golf courses, Golf courses not only contribute to the user's physical fitness, but they do also offer wellbeing through tangible amenities such as dining facilities, walking paths, parks and shopping. Intangible amenities are likewise important and can include pleasant views, nearby recreational activities, and security, all of which add to the total attraction of the golf course and the potential for including new users on the course.

Research indicates that access to green areas is important, and that experiences in these areas are diverse and multifunctional; hence, the areas have to comply with many different forms of recreational uses (KAPLAN and KAPLAN, 1989; HARTIG et al., 2003; TYRVÄNIEN et al., 2007; VAN DEN BERG et al., 2007; VELARDE et al., 2007). Thus, for this research we considered golf courses as green recreational areas that included landscape views, forest and other land uses related to landscape and recreation. To properly describe the various uses of these golf courses a method was created for mapping the golf course ecosystem. The intent was to describe the recreational potential of the golf course – one that was diverse and multifaceted to be effectively utilized not only by golfers but also by the general public.

Material and Methods

CASPERSEN and OLAFSSON 2006, 2010 developed a method for the classification of recreational experiences based on the ROS (Recreational Opportunity Spectrum) planning frame (DRIVER et al. 1987) and the REP scale (Recreation Experience Preference scale) (MANFREDO et al., 1996). These methods divides the recreational experiences into a number of different classes that follow a scale from wilderness areas i.e. areas that are natural and are not managed to more anthropocentric dominated areas that include facilities and service functions for the visitors. For this project we refined the mapping procedure by including thematic indicators for the different mapping themes that were useable at a golf course ecosystem analysis and mapping five Scandinavian golf courses: Hornbæk Golf Course is a 18 hole park course located in the country side, Denmark; Sydsjælland Golf Course a 18 hole course located in nature area next to the small town Mogenstrup, Denmark; Viksjø Golf Course an 18 hole course just outside Stockholm, Sweden; Nes Golf Course a 9 hole course in Rejkjavik, Iceland and Fredrikstad Golf Centre, a new 18 hole golf couse on a multifunctional areal with a long time depth in the fringe of Fredrikstad Norway.

At each golf course the ROS and REP scales were used to divide the studied course into the following classes:

1. Wilderness (i.e. untouched / not managed nature areas),
2. Feeling of forest (the sensation of being surrounded by threes),
3. Panoramic views (large open views), water and scenery (view that scenic and views to or across a lake),
4. Biodiversity (mapping of areas managed in sustainable way that increases the biodiversity),
5. Cultural history (visual elements that indicate a long time depth),
6. Activity and challenge (facilities and areas in which special activities or challenges can take place i.e. other sports that golf),
7. Service and gathering (toilets, restaurants, shelters etc. and
8. Safety (areas that are not safe/flying golf balls).

Maps for the different courses have been produced using ArcGIS mapping system.

Results and Discussion

Information from the mapping analysis was used in discussions with the different golf courses in order to reveal the multifunctional potential at their course and to create a plan for enhancing recreational experiences and multifunctional developments.

Hornbæk Golf Club is located 45 km north of Copenhagen in the North Zealand cultural landscape approx. 5 km from the north coast. At Hornbæk Golf Course the discovered potential for further recreational use consisted of other land uses i.e. accessible land for orienteering, which resulted in collaborations with the nearby orienteering club and two events conducted at the course. Additional potential for multifunctionality at this course was seen through the connection with the nearby forest, and running, walking and skiing trails. In spring a route with virtual marks will be tested.

Sydsjællands Golf Course is located 10 km from the nearest larger city (Næstved) in a landscape that comprises designated and protected geological elements i.e. an 10 km long esker that provide beautiful scenic viewpoints and recreational paths and nature area. Mapping included the surrounding landscape to address a possible expansion to include activities such as walking, running and bicycling. The golf club is considering the transformation of the golf club to a country club in order to make it more attractive to a group of new users.

Viksjö Golf Course is located in a cultural landscape (in the outskirt of Stockholm), and there are several historical remains as runic stones that stems from the Viking age, historical roads and farms on the course and in the surroundings. These were mapped and included in the plan for a potential development of thematic trails that focus on landscape history.

Using the mapping tool on the participating golf courses helped to elucidate the multifunctional potential of these courses. The conclusion from this project so far is that the mapping tool might be one that every golf course can use in order to reveal its potential. The tool that was developed is easily available and do not demand any knowledge of GIS and the analysis can be carried out by use of aerial photos as well digital or paper maps.

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Transition from cool-season to warm-season grass: environmental effects in a golf course in the North of Italy

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Introduction

Since the beginning of the century, communitarian and regional policies have focused their attention on the sustainability of anthropogenic action, including the management of golf courses. Despite the environmental benefits (BEARD and GREEN, 1994), turfgrass has also ecological costs related to the greenhouse gases (GHGs) emissions involved in the maintenance operations (BARTLETT and JAMES, 2001; SELHORST AND LAL, 2011).

A common challenge for maintaining turfgrass surfaces at a high level of quality is the reduction of nitrogen (N) fertilization and the water usage. Several studies focused the attention on the fate of N, regarding the pollution of groundwater aquifer, the increasing of atmospheric N_2O and the scarcity of water (CROCE, 2001; BREMER, 2006)

However another important issue is the assessment of the environmental costs due to fossil fuel emissions regarding turfgrass maintenance activities. In order to guarantee high amenity and playability quality levels, intensive management is frequently considered essential. Nevertheless few approaches cast doubt on this postulate, indicating new possibilities for more sustainable management, without renouncing to high standards. Traditionally, cool-season grasses have been used in Italy for establishing high maintenance turfgrasses (CROCE, 2003). In the last decade some studies demonstrated the adaptability of warm-season grasses to the Italian climate, as far north as the N 45° parallel. The resulting benefits have been experienced by several applications in sport fields, golf courses and residential lawns (MIELE, 2000; CROCE, 2001; DE LUCA, 2008). The use of warm-season grasses reshape the maintenance activities while reducing water consumption, fertilizer inputs, pesticides application, and the frequency of determinate interventions. The reduction of machinery working time implies less CO_2 emissions from fuel combustion, according to the EU policies (IPCC, 2013). The transition from cool-season to warm-season grass has been proposed as an effective strategy in the different Italian temperate climates for reducing golf course footprint.

The goal of this study is to assess the environmental effects of two different maintenance approaches in a 9 holes golf course in northern Italy.

Materials and Methods

Under the Köppen climate classification, most of Italy has a temperate climate (humid subtropical in the North and Mediterranean in the South) that combines cold winters with drought and high temperatures in the summer. Italy, excepted for Sicily, is considered a transition zone for turfgrasses. In these regions cool-season grasses can find good growing conditions during winter and intermediate seasons, while they suffer from heat stress and water limitation in summer. On the contrary warm-season grasses are characterized by winter dormancy and persistent straw-brown color in winter, but they give high quality turfs in summer thanks to low water use and superior drought resistance.

The study was conducted at the Golf della Montecchia, located in Padua, (45°23′N, 11°46′E) in the eastern end of the Padan Plain.

In June 2010 the golf course converted tees and fairways of the white course (9 holes) from cool-season to warm-season grasses. Original mix on fairways was *Poa pratensis*, *Lolium perenne* and *Festuca rubra*, with presence of common bermudagrass and *Poa annua*, while on tees Agrostis stolonifera cv. Penncross dominated. The bermudagrass (*Cynodon dactylon x transvaalensis* cv. Patriot) that substituted cool-season species reached 100% ground cover after 42 days from small plants establishment.

The superintendent Brian OgO'Flaerty monitored from 2007 to 2013 the cultural operations effectuated in the different playing areas, surveying the annual amount of engine working times. The data processing consisted in the comparison of data collected during 3 years before (from 2007 to 2009) and 3 years after transition (2011 to 2013). Data from 2010 was not considered because of the coexistence of both C3 and C4 species. Furthermore, data are altered by extra cultural operations needed for transition.

The engine working time were documented for machinery and equipment utilized for mowing, verti-cutting, fertilization, topdressing, coring, agrochemicals application and other cultural operations (green rolling, grooming, hydro jet use and dew removing, brush cutting, single rotary mowing, overseeding, brush and tree pruning, repairing divots, raking bunkers, and mowing of bunker edges, leaf blowing and irrigation system maintenance).

Results and Discussion

Figure 1 shows the annual amount of the machinery working time before and after the transition process, divided for each cultural operation. Values refer to the average of 3 years, both before and after transition.

Cultural operation	tees + fairways (before transition)	tees + fairways (after transition)	delta %
mowing	688	503	-27%
verticutting	12	33	+172%
fertilization	29	13	-53%
coring	41	20	-50%
topdressing	49	39	-20%
pesticides application	40	0	-100%
Total + 10%*	**945**	**670**	**-29%**

Fig. 1: Engine working time (hours) spent for cultural operation on tees and fairways before and after 2010. * indicates unexpected operations (+10%).

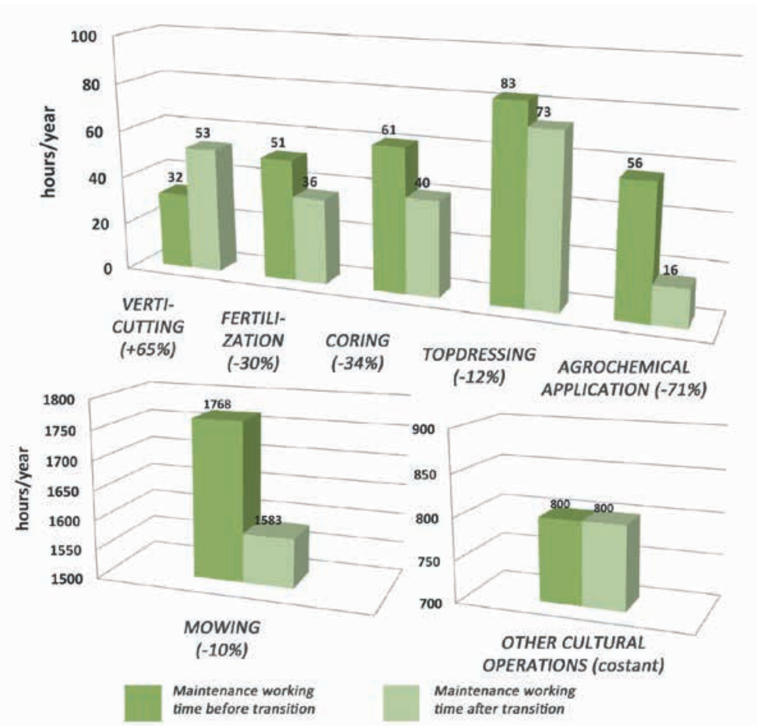

Fig. 2: Annual amount (average of 3 years) of the maintenance working times in the whole surface of the 9 holes. In brackets the delta (%) for each cultural operations between the amount of hours before and after transition.

The annual amount of hours spent in tee and fairways reduced almost 30% after 2010. Bermudagrass demonstrated an excellent adaptation and confirmed to require fewer inputs than most cool-season turf, according to the former studies effectuated at the same latitudes (DE LUCA, 2008).

Mowing activities after transition reduced 27%, accounting for 75% of total hours saved (data not showed). Despite bermudagrass requiring a great deal of mowing during the summer months, the total amount was lower because the active grow period of warm-season grass is shorter compared to cool-season grass. The reduction of N needs (more than 50%) and pesticides (100%) implied a lower use of machinery for the applications. Also the water saving due to the drought tolerance of warm-season turf cut down energy consumption for irrigation pump and engines (data not present in the study).

Verti-cutting was the only cultural operation that increased the machinery working time after transition (+172%). Bermudagrass is characterized by an extensive deep root system and significant lateral growth (rhizomes and stolons) may cause thatch accumulation if not managed. To maintain high quality turf the frequency of verti-cutting was more than doubled.

Despite tees and fairways represent only 16% of the surface of the 9 holes, their influence after transition on the amount of hours of maintenance was appreciable (-8%). Mowing represented the activity with higher reduction of hours, -185 hours/year, that accounted for more than 80% of total hours saved (data not showed). The activities under the item “other cultural practices” were not involved by the transition and they remained stable.

Conclusion

The transition from cool-season to warm-season grass permitted a more environment friendly maintenance. The study confirmed that warm-season grass requires fewer input (N, pesticides and water) and less hours of work, reducing CO_2 emissions from machinery fuel combustion. Mowing showed the greatest reduction of working time, thanks to the lower frequency intervention, accounting for 75% of total hours saved. On the contrary verti-cutting represented the only activity to increase the hours of work.

Despite the climate of the North of Italy, *Cynodon dactylon x transvaalensis* cv Patriot demonstrated an excellent resistance to thermal limits and a good wear tolerance. Thanks to the several environmental benefits above mentioned the transition contributed to the reduction ofthe golf course footprint.

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Carbon fluxes in turfgrass under different management intensities in a golf course in northern Italy

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Introduction

The increasing concentration of greenhouse gases (GHGs) in the atmosphere is strongly related to the global warming (IPCC, 2013). Among them, carbon dioxide (CO_2) originating from human activities is the largest contributor to the total radiative forcing. Promoting soil C sequestration in managed ecosystems has been proposed as an effective GHGs mitigation strategy (LAL et al., 1999). Therefore to understand the mechanisms driving the carbon (C) assimilation on terrestrial ecosystems became extremely important in order to minimize the C footprint of agriculture and turfgrass management practices. Several studies investigated the potential of turfgrass ecosystems to sequester C (QIAN and FOLLET, 2002; BANDARANAYAKE et al., 2003; HUYLER et al., 2013; SELHORST and LAL, 2013). However their role in continental and Mediterranean climates is not yet clearly understood because environmental factors and management practices can strongly influence their overall C balance. Several approaches have been used to estimate C sequestration in turfgrass: analysis of soil organic carbon (SOC) changes over time, isotopes techniques, remote sensing, measurement and modeling of gas exchange.

The objective of this study was to assess the turfgrass C sequestration, through the estimate of the net CO_2 exchange between the atmosphere and the ecosystem (Net Ecosystem Exchange, NEE) during one year, in a golf course in northern Italy.

Materials and Methods

The C sequestration potential of the turfgrass was assessed in a golf course hole, using a small-chamber enclosure approach. The measurements of gas exchange between ecosystem and atmosphere allowed for the NEE estimate as a function of different management intensities.

The study was conducted at the Golf Club Verona, located in Sommacampagna, (45°24′0″ N, 10°51′0″ E) in the province of Verona (Italy) during one year, from August 2012 to September 2013. The course includes different playing areas, characterized by different turfgrass species and management intensity. All the species were cool-season grasses.

Within the course, 20 NEE measurement points were marked with iron plates positioned in different playing areas. These areas were then grouped in 3 categories according to their degree of maintenance: high intensity (HI), tees, green and collar, medium intensity (MI), fairway and semi-rough, and low intensity (LI), rough and bunker edge. The number of measuring points repeated for playing areas was proportionate to their relative extension. HI, MI and LI had respectively 4, 8 and 4 measurement points.

Whole-canopy gas exchange measurements were performed with a portable Infra Red Gas Analyser (IRGA; EGM4, PP Systems, UK) equipped with a canopy chamber (CPY-2, PP Systems, UK) of 14.6 cm of diameter and 2425 cm^3 of volume. The portable chamber is specifically designed for measuring canopy CO_2 fluxes in a closed system. It is transparent and equipped with a fan and sensors for measurement of photosynthetically active radiation (PAR) and air temperature.

Fig. 1: Measurement during field survey; portable IRGA-EGM4 (PP Systems, UK), connected to a custom chamber, and iron plates marking NEE measurement points.

The measures were carried out, during the course of one day, every 2 weeks, for a total of 23 times over one year. Each survey consisted of 5 measures taken at different times, 5:30, 9:30, 14:00, 18:00 and 22:00, in each of the 20 points. Each sampling was executed in random order. The chamber was positioned always in the same spots.

The IRGA integrated sensors provided a) a value of CO_2 flux (µmol m^{-2} s^{-1} CO_2) as an estimate of NEE, b) air temperature (°C) and c) the photosynthetically active radiation (PAR, µmol m^{-2} s^{-1}) inside the chamber.

The integration among the 5 measurements of C flux in a single point was obtained with the trapezoidal method (PANZACCHI et al., 2012). Calculated daily values of NEE were considered representative of the period between one measurement time and the following (approximately 15 days) and used to calculate the annual NEE with the same method.

All statistical analyses were made with Statgraphics Centurion XV (StatPoint Inc., USA). Normality of the NEE annual data was tested with the Shapiro-Wilk test. One-way analysis of the variance (ANOVA) was performed to test the effect of the management intensity on the annual cumulated values of NEE. A multiple comparison procedure was then used to analyse statistically significant differences among means using the Tukey's honest significance test ($p<0.05$). Homogeneity of variance was checked using Levene's test before analysis.

Results and Discussion

Figure 2 shows the trend of NEE for each category of maintenance intensity. From November to March the trend tended to 0 for all the categories: C sequestrated during the daytime resulted slightly greater than C emitted during the night. Whereas from spring to autumn daytime assimilation increased due to higher PAR, compared to the previous colder period. At the same time high temperatures influenced daily NEE, increasing respiration of epigeous turfgrass and decomposition of turfgrass clippings. The CO_2 released in those processes exceeded that sequestered by photosynthesis, hence NEE during this period assumed positive values (Figure 2).

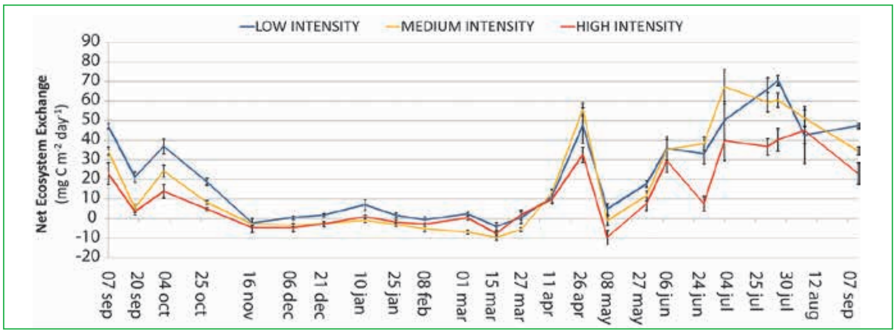

Fig. 2: Annual trend of daily net ecosystem exchange (NEE) of turfgrass under different management intensities. Bars are SE of the mean, n= 4 for LI and HI, 12 for MI.

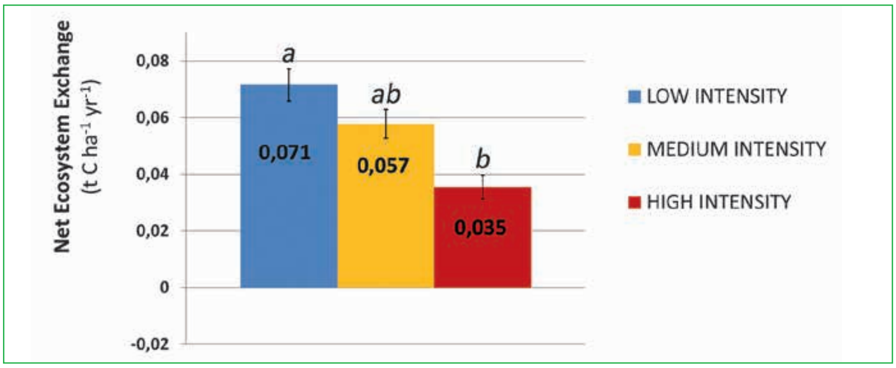

Fig. 3: Annual cumulative NEE of turfgrass under different management intensities. Values are means, n=4 for LI; 12 for MI; 4 for HI. Bars are SE of the mean. Different letters indicate statistically significant differences, p<0.05.

The annual NEE for each maintenance category resulted in a negligible C source (Figure 3). Our estimates are comparable with those of other small chambers studies available in literature (e.g. BREMER and HAM, 2005; LEWIS, 2010), however they are in contrast with those obtained with different measurement approaches (SOC chrono-sequences, ecosystemic-, LCA-, isotopic- and remote sensing-models) that generally report negative values of NEE, considering turfgrasses as a C sinks (e.g. QIAN and FOLLET, 2002; MILESI, et al., 2005; BARTLETT and JAMES, 2011). The small absolute figures of the NEE suggest a system almost in equilibrium, where C inputs nearly balance C outputs. The relation between NEE and management intensities shows that NEE significantly decreases (minor C emissions) with higher intensity (Figure 3) indicating a more conservative behaviour in terms of C for playing areas with higher maintenance. A possible explanation for this is that maintenance activities such as mowing, fertilization and irrigation may accelerate biogeochemical cycles, increasing the total amount of C fixed by plants (Gross Primary Production, GPP) and the C allocation below ground.

Conclusion

Our annual NEE estimation for a golf course turfgrass shows a system almost at a steady situation in terms of C emissions, with significant differences between turf management intensities, with less intensively managed areas behaving as greater C sources than the ones more intensively managed.

For intensive managed ecosystem further research regarding the assessment of hidden C cost due to maintenance should be carry out, in order to understand the real C footprint of turfgrass in continental and Mediterranean climates.

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Various fertilizer sources for mitigation of greenhouse gas emissions from golf course greens and roughs

Walker K.S. and K.W. Nannenga

Introduction

The concentration of carbon dioxide (CO_2) in the atmosphere is increasing at an unprecedented rate, due primarily to fossil fuel burning and land use change. The increased awareness of this global problem has led to increased pressure by society to minimize the impacts of elevated atmospheric concentrations of greenhouse gases (GHG).

Nutrient cycling on golf courses has the capacity to sequester GHG through the accumulation of soil organic carbon (QIAN and FOLLETT, 2002; MILESI et al., 2005). However, cultural management practices can offset sequestration by mitigating GHG emissions directly (fertilization) or indirectly (maintenance equipment) (BARTLETT and JAMES, 2011).

Fertilizer application, irrigation, and other turfgrass management practices have the potential to contribute to emissions and mitigation of greenhouse gases, leading to uncertainties in the net contribution of turfgrass ecosystems to climate change (ZHANG et al., 2013). Fertilization of turfgrass has been shown to increase soil nitrous oxide (N_2O) emissions ranging from 0.5 to 6.4 kg N ha^{-1} yr^{-1} (GUILBAULT and MATTHIAS, 1998; KAYE et al., 2004; BREMER, 2006; GROFFMAN et al., 2009; LIVESLEY et al., 2010; TOWNSEND-SMALL and CZIMCZIK, 2010; ZHANG et al., 2013). MAGGIOTTO et al. (2000) found that urea-based fertilizers minimized N_2O emissions and indicated that long-term effects of slow-release urea based fertilizers still need to be studied.

Choice of fertilizer release (fast versus slow release) and mechanism of fertilizer break-down needs to be considered as a method for mitigating GHG emissions. Therefore, the purpose of this project was to determine the impact of fertilizer source (Urea, Encapsulated Polyon and Milorganite), turfgrass species (*Agrostis stolonifera* L. and *Poa pratensis* L.), and site location (soil moisture regime) have on GHG (carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) emissions and overall turfgrass quality.

Materials and Methods

This field study was conducted at Lincoln Park golf course in Grand Forks, North Dakota (USA). Three sites on the golf course were selected based on cultural intensity, turfgrass species, and soil moisture regime. The first site was located on a creeping bentgrass (*Agrostis stolonifera* L.) practice putting green consisting of a sand-based root zone. The second site was located in a Kentucky bluegrass (*Poa pratensis* L.) rough with low soil moisture. The final site was located in a Kentucky bluegrass (*Poa pratensis* L.) rough with high soil moisture. Plot size was 0.61 m x 0.61 m and treatments were replicated four times.

Plots were fertilized May through October with an annual nitrogen (N) rate of 245 kg N ha^{-1} yr^{-1}. During the months of May, September, and October, a rate of 49 kg N ha^{-1} was applied to each plot. For June, July, and August, 24.5 kg N ha^{-1} was applied to each plot. Three sources of fertilizer were used: Urea (46-0-0), Encapsulated Polyon (30-0-15), and Milorganite (5-2-0). Urea is a fast-release N source whereas both Encapsulated Polyon and Milorganite are slow-release N sources. In addition, Milorganite is a natural organic fertilizer. Monthly applications were applied the first week of each month throughout the growing season.

GHG sampling was initiated on 6/5/2013 and occurred weekly until 10/26/2013. At each sampling date, gas samples were taken using a vented closed gas chamber that was placed over the plots for 40 minutes following the United States Department of Agriculture-Agricultural Research Service Greenhouse gas Reduction through Agricultural Carbon Enhancement network (USDA-ARS GRACEnet) methods (FOLLETT, 2010). Samples were taken from the same location throughout the summer as the anchors for the gas chambers were tamped into the ground flush with the soil surface at the beginning of the season (Photo 1). To ensure a good seal, the tops of the gas chambers were also tapped in after they were placed over the anchors (Photo 2). Gas samples were taken at 0, 20, and 40 minutes post closure of the chamber (Photo 3). This method allows gas concentrations to build up inside of the chamber, and a flux rate of the gases from the surface to be calculated based on the change in concentration over time. In addition, at each sampling date air temperature, soil temperature, soil moisture, turfgrass quality and canopy greenness data were collected. Turfgrass quality was on a visual rating of 1 to 9 where 1=bare soil, 6=minimally acceptable, 9=optimum uniformity, density, and greenness. Canopy greenness was assessed using a CM 1000 (NDVI Meter; Spectrum Technologies) chlorophyll meter.

Results

Preliminary data analysis on the first four sampling dates in June 2013 (6/5/2013, 6/12/2013, 6/19/2013, and 6/26/2013) showed a trend ($p<0.1$) indicating higher CO_2 emissions on the green than on the two rough sites (Figure 1). In addition, preliminary results also show CH_4 emissions ($p<0.05$) higher in the control than in the Encapsulated Polyon treatment across all sites (Figure 2). In addition, site ($p<0.001$) influenced N_2O emissions; although treatment ef-

Photo 1: Anchors for each plot were tamped into the soil at the beginning of the study to provide a base for the gas chambers.

Photo 2: Prior to sampling for greenhouse gases, the gas chambers were tapped onto the anchors to create a good seal.

Photo 3: Gas samples were taken at 0, 20, and 40 minutes post closure of the gas chamber and anchor.

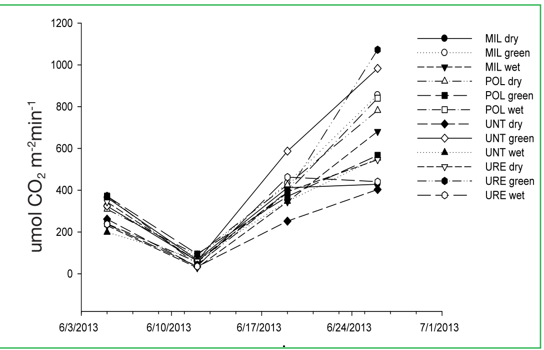

Fig. 1: 2013 CO_2 flux for the first four sampling dates. Dry=dry rough; green=putting green; wet=wet rough; UNT= Control, URE= Urea, POL= Encapsulated Polyon, MIL=Milorganite.

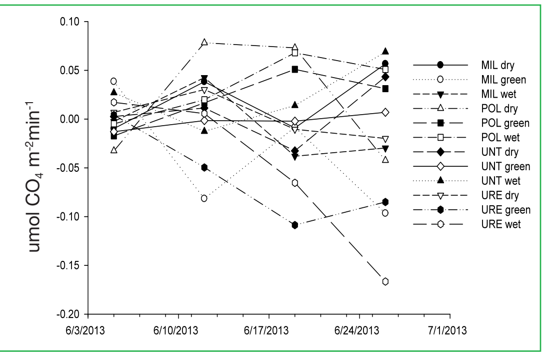

Fig. 2: 2013 CH_4 flux for the first four sampling dates. Dry=dry rough; green=putting green; wet=wet rough; UNT= Control, URE= Urea, POL= Encapsulated Polyon, MIL=Milorganite.

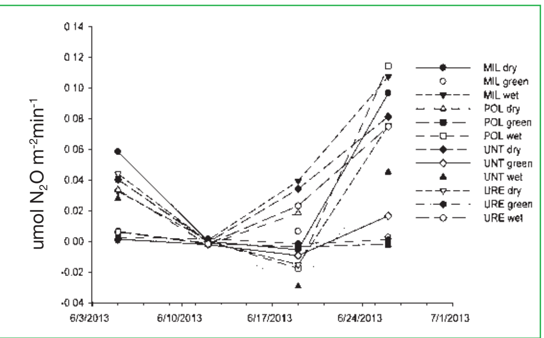

Fig. 3: 2013 N_2O flux for the first four sampling dates. Dry=dry rough; green=putting green; wet=wet rough; UNT= Control, URE= Urea, POL= Encapsulated Polyon, MIL=Milorganite.

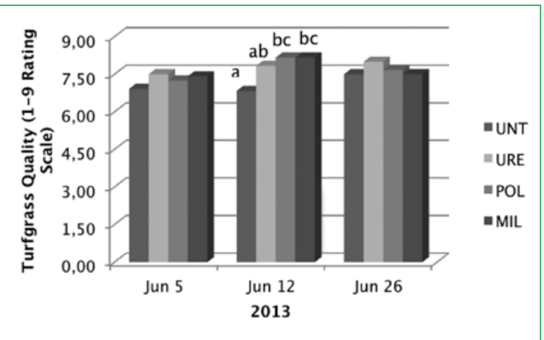

Fig. 4: Mean turfgrass quality (1-9 Rating Scale; 1=Bare soil, 6=Minimally acceptable, 9=Optimum uniformity, density, and greenness) for all turfgrass areas (UNT= Control, URE= Urea, POL= Encapsulated Polyon, MIL=Milorganite).

fects were not significant (Figure 3). On the four sampling dates analyzed, the rough in the dry location showed higher N_2O emissions than the other two sites; this trend was consistent across sampling dates. Interestingly, on the first sampling date the rough in the wet location showed a negative flux of N_2O, suggesting at times this location can act as a sink for N_2O which is a potent greenhouse gas. Previous investigators have observed negative fluxes of N_2O (VIETEN et al., 2009; RICHARDSON et al., 2009; CLOUGH et al., 1999). Explanations offered include the reduction of N_2O to N_2 (VIETEN et al., 2009) with the denitrification enzyme N_2O reductase (RICHARDSON et al., 2009). CLOUGH et al. (1999) quantified that 2/3 of the total soil N2O was reduced to N2 before ultimately being released from the soil. The conditions reporting negative N2O fluxes are quite variable, suggesting that abiotic mechanisms or unidentified biological sinks may be operating (SMITH, 2010).

For turfgrass quality, each sampling date was analyzed by turfgrass area, fertilizer treatment, and turfgrass area x fertilizer treatment interaction. There were differences ($p<0.05$) in site location for the June 5 sampling date where turfgrass quality was lower on the green (6.9) than either site locations in the rough (7.4). For the June 12 sampling date, turfgrass quality was significantly ($p<0.0001$) higher for the Encapsulated Polyon and Milorganite treatments (8.4) compared to the control (6.8) (Figure 4). Sampling will begin again in May 2014.

Conclusions

The results from this two-year field study will provide information about turfgrass management practices that minimize greenhouse gas losses for cool-season turfgrasses which can be utilized to evaluate the environmental efficacy of our current cultural management practices.

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Optimal application intervals for the plant growth regulator Trinexapac-ethyl (Primo MAXX®) at Northern Latitudes

Aamlid T.S. and Geo J.L. van Leeuwen

Introduction

The plant growth regulator Primo MAXX® (PM, trinexapac-ethyl) is approved for use on turf in Sweden and Iceland, and applications for registration have also been filed in Finland and Norway. PM inhibits the conversion of GA_{20} to GA_1, i.e. the last step in plant biosynthesis of the plant hormone gibberellic acid (ADAMS et al., 1992). Because PM is not persistent in plant tissue, it must be reapplied at regular intervals to have a consistent effect on cell elongation and turfgrass clipping yields. Application intervals of 1-2 weeks on greens and 2-3 weeks on fairways were recommended based on trials on Nordic golf courses (AAMLID et al., 2009). If application intervals become too long, turf treated with PM will rebound, i.e. grow faster than the untreated turf after PM is no longer suppressing growth (LICKFELDT et al., 2001; BRANHAM and BEASLEY, 2007). Research in Wisconsin, USA, has shown that the duration of growth suppression depends on temperature, and that optimal application interval in the northern US (40-49 °N) is 200 Growing Degrees Days (GDD) with a base temperature 0 °C (KREUSER and SOLDAT, 2012).

The Nordic countries are located at 56-71 °N and the maximum daylength at midsummer ranges from 18 to 24 h. For grasses native to this region, it is well documented that the long summer days have a strong impact on leaf elongation and dry matter production, especially at cool temperatures, and this effect may well be mediated by GA_1 as discussed by (HAY, 1990). It can therefore be hypothesized that the rebound effect will occur faster at higher latitudes than at low latitudes, although it remains to be established how the combination of low summer temperatures and long days will influence turf metabolism of trinexapac-ethyl. Thus, the objective of this research was to study the effect of increasing temperature and daylength on the duration of growth suppression, expressed in GDD, after application of PM.

Materials and Methods

Plant material was taken on 5 Aug. 2013 from a sand-based green seeded 10 weeks earlier with a creeping bentgrass (*Agrostis stolonifera*) seed blend consisting in equal parts of the cultivars 'Penn A-1', 'Penn A-4', 'Penn G-6' and 'Declaration'. The trial was located at Bioforsk Landvik, Norway (58°20′ N). Undisturbed cores, each 10 cm wide and 20 cm deep, were sampled with a cup cutter and placed in pots of similar size. The experiment was conducted from 6 Aug. to 30 Sep. in growth chambers with a PPFD (Photosynthetic Photon Flux Density) of 269 ± 19 µmol/m^{-2}/s^{-1} of fluorescent plus incandescent light for 10 h per day. Daylength extension was given as incandescent light (2.2 µmol/m^{-2}/s^{-1}) for an additional 5 or 10 h. The experimental plan comprised three factors, each with three levels:

Factor 1: Diurnal mean temperature	Factor 2: Day-length	Factor 3: Dose of Primo MAXX
13.2 °C	1. 10 h	i. Unsprayed
19.3 °C	2. 15 h	ii. 0.8 L ha^{-1}
24.1 °C	3. 20 h	iii. 1.6 L ha^{-1}

The experiment was carried out in two separate sections (statistical blocks) of the research center, each containing three growth chambers, each 12 m^2. Temperatures were set to 10, 16 and 22 °C, but loggers showed the above values at plant level due to the radiant energy from the fluorescent light. The design was a split-split plot with temperatures (growth chambers) as main plots, daylength as subplots (three trolleys per growth chamber) and plant growth regulator as sub-subplots (pots). The target daylengths were obtained by covering two of the trolleys in each growth chamber with a black impermeable curtain for 5 and 10 h (Photo 1). Each trolley carried three parallel pots per growth regulator treatment; this was considered a random factor in the statistical analyses. All pots were fertilized weekly with a complete liquid fertilizer solution (Wallco 5-1-4, Cederroth International AB, Falun, Sweden) at 0.7 N m^{-2} wk^{-1}. PM was applied on 21 Aug. using an Oxford sprayer working at 150-200 kPa pressure. The turf was clipped at 10 mm twice per week and clipping dry weight, plant height, and turfgrass colour (1-9, 1 is completely discoloured, 9 is intensely green) were determined. In addition to ANOVA, cubic regression with GDD as the independent variable was used to express the effect of temperature and daylength on relative clipping yield (unsprayed = 100).

Results and Discussion

On average for eleven observations during the six weeks after application of PM, the rise in mean diurnal temperature from 13.2 to 19.3 resulted in a 32% increase in clipping yield and a 28 % increase in height growth (Table 1). The reason why these effects were not statistically significant can partly be ascribed to the wide temperature optimum for net photosynthesis of C3 grasses (FRY and HUANG, 2004), and also that the experimental setup allowed only two replicates (growth chambers) for each temperature.

Daylength extension from 10 h to 20 h gave a 28% increase in clipping yields and a smaller and insignificant (13%) increase in turfgrass height growth (Table 1). It should be noted that this was a true photoperiodic effect as the incoming radiation was virtually the same in all treatments. The results are in agreement with the studies reviewed by HAY (1990) and indicate a true photoperiodic response even in North American cultivars of creeping bentgrass although the increase in clipping yields due to daylength extension from 15 to 20 h was less than would be expected from more northerly adapted plant material.

The strongest and highly significant effects on clipping yields and daily height growth were due to PM (Table 1). In agreement with recent studies showing mostly linear dose responses to PM (VÅGEN et al., 2013), the average re-

Photo 1: Different daylenths were obtained using low-intensity incandescent light and covering trolleys with black, impermeable curtains. (Photo: Geo van Leeuwen)

Table 1

		Daily production of clippings g DM m^-2	Daily height increment, mm (mean of 10 obs)	Color (1-9, 9 is most intensely green)
Mean diurnal temperature	A. 13.2 °C	1.14 a[1]	2.9 a	7.3 a
	B. 19.3 °C	1.42 a	3.4 a	6.8 a
	C. 24.1 °C	1.50 a	3.7 a	6.4 a
Daylength	1. 10 h	1.22 b	3.2 a	6.8 a
	2. 15 h	1.28 b	3.2 a	6.7 a
	3. 20 h	1.56 a	3.6 a	6.9 a
Primo Maxx	i. Unsprayed	1.74 a	4.1 a	8.1 a
	ii. 0.8 L ha^{-1}	1.32 b	3.2 b	6.5 b
	iii.1.6 L ha^{-1}	0.99 c	2.7 c	5.8 c

1 For each main effect, means followed by the same letter are not significantly different according to $LSD_{0.05}$.

Table 1: Main effects of temperature, daylength and Primo MAXX on daily production of clippings, daily height increment and turf color. Means of observations from 24 Aug. to 3 Oct., i.e. during the six week period after application of PM.

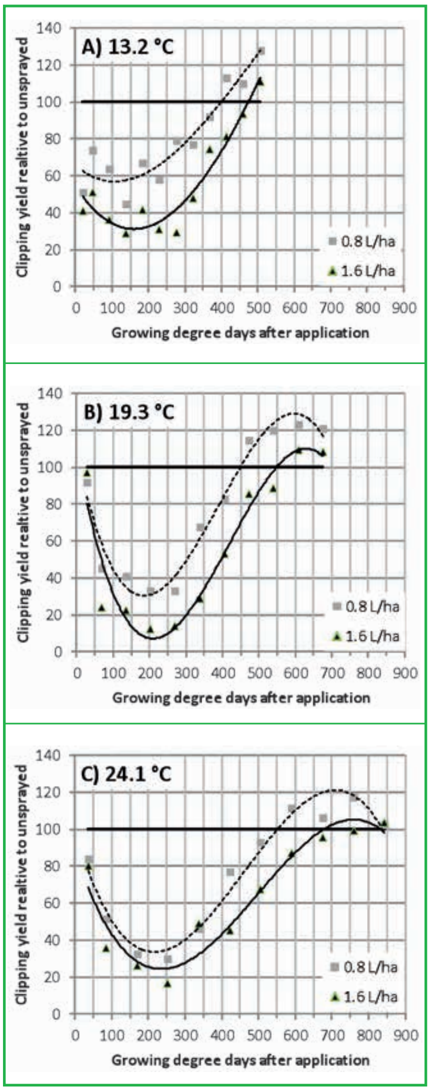

Fig. 1: Relative clipping yields (untreated control = 100) expressed as cubic functions of growing degree days after application of two rates of Primo MAXX at three temperatures. Means of three daylengths.

duction in clipping yield was 24% and 43% after application of 0.8 and 1.6 L ha^{-1}, respectively. These high rates are more relevant for fairways than for greens, and in this experiment, they caused significant reductions in turf colour, even at 10 mm mowing height. We have previously reported the appearance of brown or yellow turf after the first application of high rates of PM in Nordic fairway trials, but these tendencies became less pronounced as the turf was accustomed to growth regulator (AAMLID et al., 2009). According to practical experience, this discoloration can also be avoided by applying small rates of nitrogen fertilizer in tank mixture with PM.

Contrary to our hypothesis, the data revealed no significant interaction between PM and daylength. It therefore seems that the rebound effect after using PM is controlled not only by GA1, but also by plant carbohydrate status, but this warrant further research under normal daylight conditions. However, if rebound is defined as when the growth rate of treated plots exceeds that of untreated plots, the data presented in Fig. 1 clearly shows that the rebound effect occurred at a greater GDD at higher temperature compared to low temperature, and also at a greater GDD at lower rather than high PM rates. While the latter is contradictory to KREUSER and SOLDAT (2012), our data mostly confirm their recommendation of 200 GDD as a rough guideline for how often PM should be applied. Nonetheless, in Iceland and other northern and coastal parts of the Nordic countries, where the mean temperature for the growing season is only 9-11 °C, an application interval of 200 GDD, i.e. approximately every 20 days, is probably too long to get the maximum benefit from the product. In fact, KREUSER and SOLDAT's (2012) data from Wisconsin, USA also showed a stronger reduction in clipping yields and significantly better turf quality when PM was applied every 100 GDD than every 200 GDD. Their argument for recommending 200 GDD was that 100 GDD would not be practical in the summer heat of the Midwest United States, but that argument is less relevant under Nordic conditions. In agreement with earlier recommendations (AAMLID et al. 2009), we therefore conclude that light and frequent applications maximise the benefit of PM on golf courses.

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Festuca arundinacea drought resistance induced by Trinexapac-ethyl

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Introduction

The growth of cool-season turfgrass species is often limited by high temperature during summer months in warm climates (JIANG AND HUANG, 2001). Another abiotic stress, drought, affects the growth of most cool-season grasses (McCANN AND HUANG, 2008). Both stresses are and will continue to be the primary concern in turfgrass management, as water is becoming increasingly limited for irrigation and temperatures are rising due to global warming (HUANG, 2004). Tall fescue (*Festuca arundinacea* Schreb) is more tolerant to heat and drought stress in comparison to other cool-season grasses (TURGEON, 2005). But, in many situations this tolerance is not enough to withstand severe hot periods during late spring and summer or long dry periods where irrigation is scarce. Greater drought resistance in tall fescue can be achieved by reducing metabolic rate during hot and dry periods, through the use of plant growth regulators (PGRs). Trinexapac-ethyl (TE) is one of the most widely used PGRs for the management of cool and warm-season turfgrass species (McCULLOUGH et al., 2006). The use of TE has already shown greater resistance to drought and heat stresses in several cool-season turfgrass species, however, limited research has been conducted on tall fescue. The objective of this research was to test TE on tall fescue, in order to demonstrate that it can be used to save irrigation water during water stress periods.

Materials and methods

An experiment was conducted in 2013 between May and July. Tall fescue cv. '3rd Millenium' was sown in the previous autumn at 25 g m^{-2} in 24 polyethylene containers (30 cm depth, 17 cm of diameter and 5.5 L of capacity) and filled with a commercial peat based substrate. The containers were placed in a greenhouse with no climatic control, only to prevent rainfall and to slightly increase the temperature. Temperature was recorded with a HOBO U23 Pro v2 temperature data logger. The monthly maximum and minimum temperatures were as follows: 30.2 °C and 9.7 °C for May, 32.6 °C and 13.6 °C for June and 37.3 °C and 17.9 °C for July. The experiment was a completely randomized design testing 2 factors: TE treatment (treated or untreated) and drought stress at 3 levels (100%, 75%, and 50% of optimal irrigation dose). Optimal irrigation dose (800 mL of water per container) was determined through observation during the adaptation months (October to May). Each drought stress group was irrigated with the corresponding water dosage on the first irrigation date of the experiment. Thereafter, only the amount of weekly water loss was supplied to the individual containers. To irrigate the plants, the corresponding dosage of water was poured individually into each container with a plastic graduate beaker once or twice per week. Primo-Maxx trinexapac-ethyl (12.5%) formulation was applied. The application dose was 2.4 L ha^{-1} of the commercial formulation (0.393 kg ai ha^{-1}) and the application dates were May 2nd, May 16th and May 30th. General aesthetics were rated weekly with a visual rating system according to the evaluator's judgment using a scale from 1 to 9, where 9 means outstanding or ideal turf and 1 being poorest or dead. Water loss was determined by weighing the containers weekly with an Ohaus ES30R scale. Substrate volumetric moisture content (7 cm depth) was also determined weekly with a WET sensor kit (Delta-T Devices, Cambridge, UK).

Results

Only plants irrigated with the optimal irrigation dose (100%) completely survived this experiment and their behaviour in terms of water saving and water content in the first 7 cm of the substrate is shown in Figure 1.

Figure 1 shows an increase in water saving just after the third application of TE (May 30th). This trend lasted roughly 1 month, until the beginning of July. During the aforementioned period, water saving average was around 15-17%, with a maximum peak of 21%. In the same Figure, volumetric water content in the first 7 cm of the substrate is shown for both TE treated plants and untreated plants. After the mowing date on June 11th, the substrate moisture content in the treated containers remained higher than in the untreated containers. The TE application on tall fescue caused growth inhi-

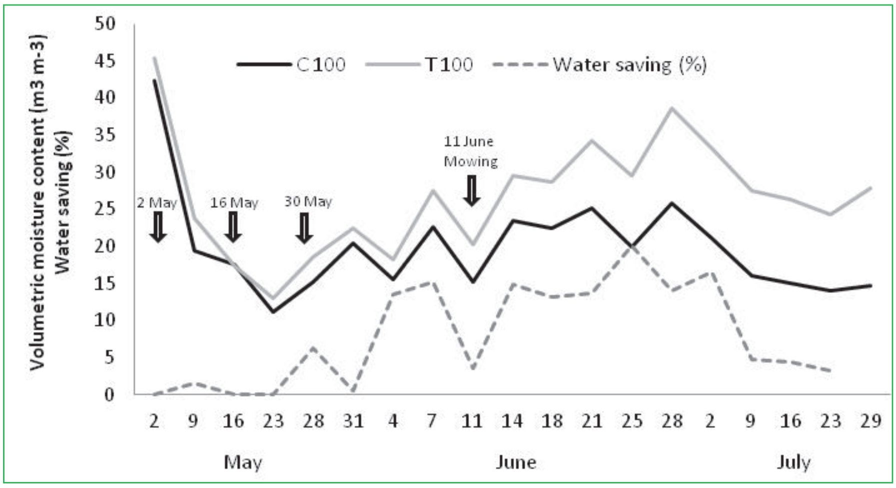

Fig. 1: Volumetric moisture content in the first 7 cm of the substrate profile (C100 = control containers; T100 = Trinexapac-ethyl (TE) treated containers) and water saving (%) by applying TE, along the experiment. TE application on May 2nd, May 16th and May 30th. Mowing event on June 11th.

bition and a lower general aesthetics score (data not shown) than in untreated plants, but it was still acceptable for a good turf quality level.

Conclusion

The results from this experiment indicate that the application of TE on tall fescue saved water. Apart from the reduction in mowing requirements, another great advantage of this type of treatment is its ability to reduce the effect of drought stress on turfgrass. This investigation suggests that TE can be used on tall fescue turfgrass prior to a heat stress period, as a method of saving around 17% of water per month, mowing with less frequency and achieving better recovering after drought stress, as more quantity of water is in the substrate. The minor disadvantage of this treatment is the negative effect on general aesthetics.

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Potassium sources and placement for bentgrass putting greens

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Introduction

Potassium uptake in plants has been studied for close to 90 years (BARTHOLOMEW and JANSSEN, 1929). In turfgrass systems, increasing applications of K fertilizer often produced subsequent increases in tissue and soil K (SHEARD et al., 1985; JOHNSON et al., 2003; FITZPATRICK and GUILLARD, 2004; WOODS et al., 2006). However, the vast majority of that work found that the application of K rarely improved other indicators of turfgrass performance. For example, application of K did not improve turfgrass quality (JOHNSON et al., 2003; FITZPATRICK and GUILLARD, 2004), increase clipping yield (FITZPATRICK and GUILLARD, 2004), further protect against winter damage (GOATLEY et al., 1994; MILLER and DICKENS, 1996) or improve wear tolerance (CARROLL and PETROVIC, 1991). The vast majority of this K research was performed on cool-season grasses, especially Kentucky bluegrass (*Poa pratensis* L.), and few K sources (K_2SO_4 and/or KCl) were evaluated. Less studied are the intensively managed systems of sand-based rootzones. Last, there are few published studies which examined various K sources, especially when including slow-release materials (SNYDER and CISAR, 1992). Thus, the objective of this research was to examine the effect of K sources, applied at the same K rate, on the performance of a creeping bentgrass (*Agrostis stolonifera* L.) putting green, and on K content and movement in the putting green. An additional factor was that the method of K placement (banded in aerification holes or surface broadcast) was also evaluated.

Material and Methods

The two-year study (2006 and 2007) was conducted on a 4 year old USGA-type (80% sand, 20% composted rice hulls) 'Penn G-2' creeping bentgrass putting green located in Auburn, AL, USA. Soil test K prior to application of K fertilizer treatments was 76 kg ha^{-1} K. Beginning in Aug 2006 the following K fertilizers were applied at a rate of 56 kg K_2O ha^{-1}: 1) KCl, muriate of potash (KCl, 0-0-60) 2) K_2SO_4, sulfate of potash (K_2SO_4, 0-0-50), 3) polymer-coated K_2SO_4 (Polyon®, 0-0-50), 4) KNO_3, potassium nitrate 13.8-0-44.5, and, 5) potassium thiosulfate ($K_2S_2O_2$, 0-0-25-17S). A zero K control was also included, and all plots received N as ammonium nitrate equal to that applied in the KNO_3 treatment. The K rate was based on the initial soil-test recommendation. Potassium fertilizer treatments were applied 4 times a year (Aug, Nov, Feb, May). The same K rate (56 kg K_2O ha^{-1}) was applied to all plots, regardless of soil test. All K treatments were applied at the same K rate via two methods: 1) surface broadcast application, or, 2) subsurface 'band' placement at the bottom of 10 cm deep (1.3 cm diam.) aerification holes. All plots were equally aerified, and then the banded K treatments were applied to the surface and swept into the aerification holes. Surface K treatment plots were first topdressed with sand to fill holes prior to fertilizer application, and then K fertilizer treatments were broadcast applied. Fertilizers were broadcast hand applied

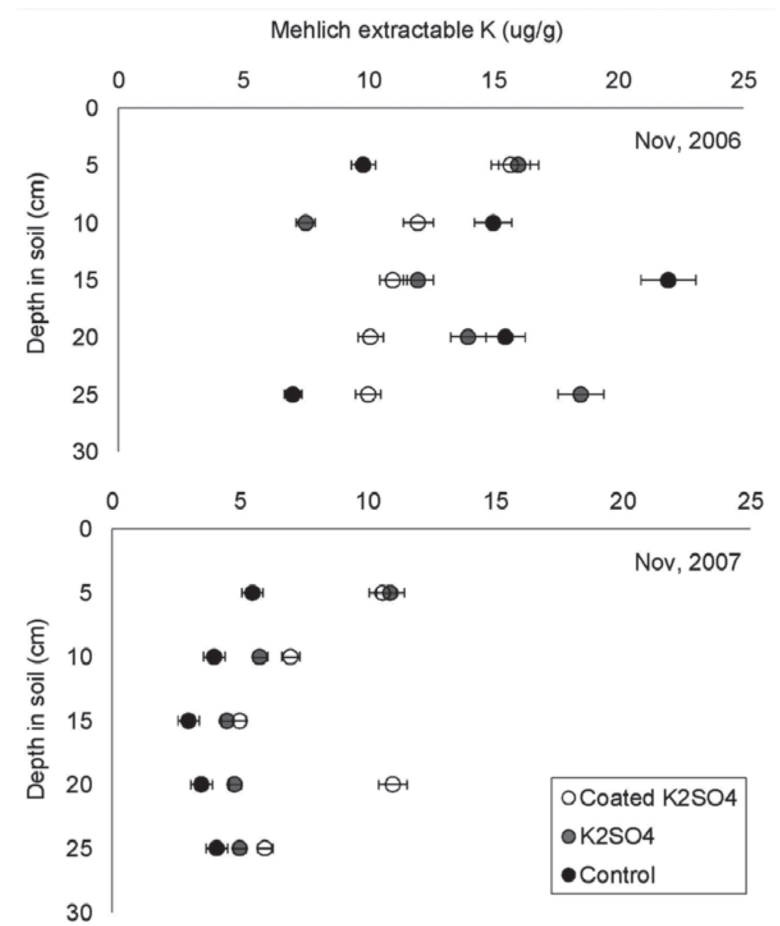

Fig. 1: Mehlich extractable K in a creeping bentgrass putting green as affected by K source and sampling depth, Nov, 2006 (top) and Nov, 2007 (bottom), Aubum, AL. Nov, 2006 samples were taken 90 days after experiment start, immediately preceding further K fertilizer application. Nov, 2007 samples were taken 455 days after experiment start. Data shown is averaged over both methods of K placement (band or broadcast) as the interaction of K source and Method of fertilizer placement was not significant. Horizontal bars on each data point are the standard error about the mean.

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in a 'checker-board' fashion, except for the potassium thiosulfate, which was a liquid formulation and was sprayed, undiluted, directly on the foliage using a CO_2 sprayer that delivered 91mL of product to the plot. Irrigation (0.6 cm) was applied immediately after application of all products. The experiment design was a 5 x 2 factorial of K source and K placement (plus an aerified control plot), with treatments arranged in a randomized complete block design of 4 replications with plot dimensions of 2.1 m x 2.7 m.

Collected data included monthly soil K content (0-7.6 cm depth), and quarterly (Aug, Nov, Feb, May) soil K content partitioned by depth (0-25 cm deep, 5 cm depth increments). All soil samples were extracted with Mehlich I extractant, and analyzed via atomic absorption (AA) spectrophotometry for K concentration. Clippings were collected each month by mowing one mower width of the plot (53 cm), the clippings dried, and yield determined. A dried subsample of clippings was analyzed for ppm K via AA spectrophotometry. Additional data collection included twice per year (July and Sept) determination of shoot density, and monthly turf quality ratings (using a 1-9 qualitative scale).

Results

In most months there were few differences in extractable soil K due to K source, and any plot that received K fertilizer had greater extractable K than measured in the unfertilized control plots. Over time, extractable K became low in all plots, and subsequent application of K at 56 kg K_2O ha^{-1} (Aug, 2006, Nov, 2006, Feb, 2007, May, 2007, Aug, 2007, Nov, 2007, Feb, 2008, and May, 2008) was not sufficient to increase soil-test K to recommended sufficiency levels.

Early in the experiment, when analyzed by depth, there was significantly more soil K at increased depths from the K_2SO_4 treatment than from the coated K_2SO_4 treatment (Figure 1). This may indicate that some downward movement of the soluble K_2SO_4 source was occurring. However, as the experiment continued over two years such differences disappeared, and no one K source consistently outperformed the other with respect to persistence in the soil profile.

The application of any K fertilizer, regardless of source, increased tissue K above that measured in bentgrass tissue from the unfertilized control. In 4 of 16 sampling dates the placement of K as a surface broadcast application produced significantly more K in bentgrass tissue, as compared to tissue K where the fertilizer had been band applied.

In 2006, plots that received applications of potassium thiosulfate had a significantly lower shoot density as compared to the unfertilized control, likely due to some observed foliar burn. There were no other differences in shoot density due to K source, and none (other than in potassium thiosulfate treatments) had better or poorer shoot density than compared to the control.

Conclusions

Over 2 years there was little difference in bentgrass performance due to K source: clipping yield, tissue K and uptake of K by bentgrass were rarely affected by source, the method of placement of that K, or the interaction of these two treatments. Downward movement of K in the soil profile was not great, and largely unaffected by K source, except early in the two-year study. Bentgrass color and quality were unaffected by K source. This research project agrees with other published studies that demonstrate little turfgrass response to K fertilization.

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Anaerobic digestate: an alternative fertiliser for the turf grass industry

Owen, A.G., I. Weir, M. Pawlett and M. Tibbett

Introduction

The production of energy from waste through anaerobic digestion forms part of a commitment by the United Kingdom (UK) government towards a 'zero waste' economy (WRAP, 2010). The process produces a nutrient rich liquid as a by-product; anaerobic digestate (AD) which has a potential use as a sustainable turf fertiliser. The nutrient content of the AD is variable depending upon the energy plant feedstock (crop residues, animal slurry, food wastes), however there is still significant market potential for AD as a fertiliser for sports turf in the UK, with large numbers of playing facilities as well as a growing area of turf production for sports and landscaping. The importance of appropriate nutrient applications to sports turf to provide wear tolerance (HICKEY and HUME, 2003) grass cover and traction (SPRING, et al. 2007) and during surface renovation, (CANAWAY, 1985) is well established. As many facilities are being managed on tight budgets with limited maintenance operations, utilising AD applications to provide plant nutrition could be a possible solution which will maintain surface quality and allow sustainable use. The key aim of the work was to conduct a statistically robust field trial to investigate the effects of Publically Available Specification (PAS) 110 compliant AD use on turfgrass and soil quality at a site in Northwest England,UK.

Materials and Methods

A randomised complete block design was used at Myerscough College, Lancashire, UK to compare a 'standard practice' mineral fertiliser nutrition strategy (SP) at 100 kg [N] ha^{-1} yr^{-1} with two application rates of liquid anaerobic digestate; applied at 100 & 200 kg [N] ha^{-1} yr^{-1} and including a zero rate control. Application rates were based on the annual Sports Turf Research Institute fertiliser application rate recommendation (LAWSON, 1996) for football/rugby pitches, which is 80-100 kg [N] ha^{-1}. The total annual N application rate was split into five equal applications made over the growing season, the trial ran for two full years. The nutrient composition of each batch of AD was determined utilising a commercial laboratory and application volumes adjusted accordingly (0.4 - 0.8 l m^{-2} application). The site, located on a sandy clay loam soil was established with a commercial winter sports *Lolium perenne* cultivar mix and maintained as a winter games surface, without wear. A suite of soil and foliar analyses, and turf quality assessments were carried out prior to, during and following treatment applications over an 18 month period.

Results

The mean nutrient content of the AD (Table 1) identifies its suitability as a turf fertiliser with an N:P:K ratio of 25:1:4. The variation encountered between the AD batches (Table 1) was expected considering the 18 month span of the project and demonstrates the need to have individual batches analysed, as the varying feedstock supplied to each AD plant will affect the AD composition.

A complete suite of soil nutrient measurements were conducted on three occasions throughout the trial. Initial measurements prior to any treatment applications showed that the trial site was relatively homogenous, with no significant differences in soil characteristics between sample plots (data not shown). Soil assessments made at the completion of the trial showed similar homogeneity (Table 2). No significant differences were identified between treatments for twenty soil characteristics.

All fertilised plots had significantly ($p<0.05$) improved greenness when compared with the control (Figure 1), the SP treatment and matched N rate of AD showed similar sward colour. Where the rate of AD application was doubled to 200 kg [N] ha^{-1} yr^{-1} sward greenness increased significantly.

Total foliar N was significantly increased in the grass plots where the AD was applied at 200 kg [N] ha^{-1}

Analysis	Mean (n=8)	CofV (%)
Total solids (%)	3.69	19.8
Conductivity (uS/cm)	6652	21.8
Total N (% w/w)	0.61	27.0
Ammonium-N (mg/kg)	4979	29.7
Total P (mg/kg)	303	19.6
Total K (mg/kg)	1131	28.9
pH	8.32	1.5
Organic Matter LOI (% w/w)	2.55	24.8

Tab. 1: Selected mean anaerobic digestate characteristics showing the coefficient of variation of all batches tested (n=8).

	Control	Standard practice	AD 100 kg [N] ha^{-1} yr^{-1}	AD 200 kg [N] ha^{-1} yr^{-1}
pH	5.9	5.9	5.7	5.7
Total N (% w/w)	0.37	0.39	0.36	0.37
Available P (mg /l)	13.0	14.0	15.3	14.0
Available K (mg/l)	176	198	203	211

Tab. 2: Selected mean soil analysis results, samples collected following trial completion.

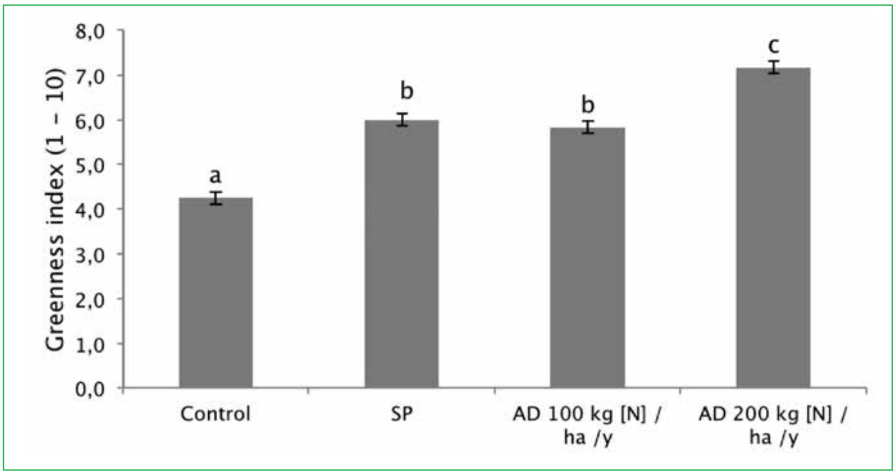

Fig. 1: Mean sward colour assessment (10 = very green) showing standard error (n=3). Letters denote homogeneous means (p=0.05).

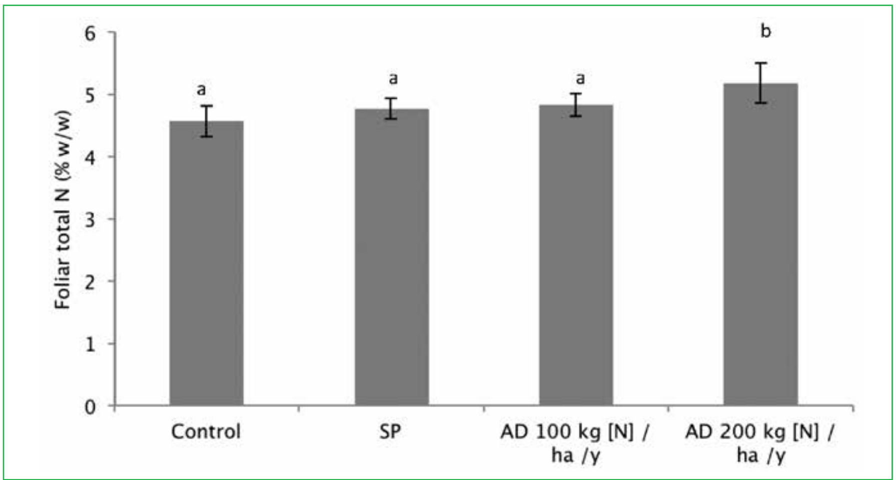

Fig. 2: Mean foliar N content showing standard error (n=3). Letters denote homogeneous means (p=0.05).

yr^{-1} compared with the other treatments (Figure 2). The SP and AD at the lower rate did not significantly alter the foliar N content from the control plots, which contrasts with the sward greenness results. Potentially changes in visually assessed sward greenness were not translated into significantly greater foliar N content.

Conclusion

Anaerobic digestate demonstrated clear potential as a turf fertiliser for winter games turf and could potentially be utilised for local authority managed pitches where tight budgets mean that fertiliser programmes are neglected or incomplete. This could potentially provide a sustainable solution where energy from waste via anaerobic digestate forms part of a local energy generation strategy. Anaerobic digestate provided an equivalent turf response to a matched N content mineral fertiliser, with no significant effect on a range of soil chemical properties and foliar analyses. However, issues of odour and even application were identified during the trial and would need to be addressed before such a product could be commercially utilised.

Acknowledgments

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Improving nitrogen use efficiency of turfgrass with controlled-release N

Cisar, J., D. Park, M. McMillan and K. Williams

Introduction

Regulatory restrictions of nitrogen (N) fertilizer by both N rate and season present a challenge to providing acceptable turfgrass systems (HOCHMUTH et al., 2012). Coated-N sources have the potential to improve sustainability of turfgrass systems through increased nutrient-use efficiency by increased N uptake at reduced rates of application (CISAR, et al. 2001). This experiment evaluated coated and uncoated slow release N sources to standard water soluble N and unfertilized lawn turf applied at reduced annual rate to the current standard in the sub-tropics. Timing was compared for 2, 3, 6 and 12 month application intervals. Effects of treatments on visual turfgrass quality, colour and quantitative measurements of yield, N content, and N uptake were determined.

Materials and Methods

Four replications of 8 N fertilizer treatments: 5 controlled-release polymer coated ureas (PCU), PCU3, PCU6, PCU and DURATION; 2 controlled-release sulfur coated, XCU and SCU; UMaxx, a urease inhibitor sparged urea, 1 soluble standard source, UREA and an untreated control (Table 1) were initiated on a randomized complete block design of 'Floratam' St. Augustinegrass 3 m x 4 m plots on 8 June 2011 with re-application of treatments based on release. Nitrogen source treatments were sprinkled over plots and watered in with 0.5 cm. Plots were mowed prior to application at 8.0 cm with clippings removed. All other plant essential elements were applied bi-monthly to maintain non-limiting nutrient levels across all treatments. Plots were rated for quality/colour (scale of 1-10 with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf) throughout the experiment. Clipping samples were removed throughout the experiment for dry weight (grams) yield determination and tissue N content [%] and N uptake (NUP) [content x yield] (CISAR et al., 2001). All data was subject to ANOVA and significant means were identified.

Results

Significant treatment effects were observed for all parameters with only

PRODUCT	N-P-K	Application Frequency days	N/Application g/m²	Applied N g/m²/year
CHK	---	---	---	---
UREA	46-0-0	60 d	5	30
XCU	43-0-0	60 d	4.5	27
PCU3	30-2-8	90 d	6.25	25
PCU6	29-2-8	180 d	11.25	22.5
PCU12	28-2-8	360 d	21	21
UMAXX	47-0-0	90 d	6.25	25
SCU	39-0-0	60 d	4.5	27
DUR	35-0-10	180 d	11.25	22.5

Tab. 1: Experiment treatments.

TRT	Yield g/m²	Tissue N %	NUP mg N/g/m²	Percent Recovery	Visual Quality	Visual Colour
CHK	4.69d	1.90c	2.39d	---	5.9d	6.4d
UREA	24.69c	2.27b	11.95bc	39.8	7.5ab	7.7ab
XCU	32.85a	2.39a	17.64a	65.3	7.6ab	7.7ab
PCU3	28.02c	2.24b	10.55c	42.2	7.5ab	7.7ab
PCU6	21.75c	2.25b	9.98c	44.4	7.4bc	7.5bc
PCU12	26.97abc	2.26b	14.9ab	70.9	7.2c	7.4c
UMAXX	21.89c	2.25b	10.45c	41.8	7.7a	7.9a
SCU	25.59bc	2.29b	12.34bc	45.7	7.7a	7.8a
DUR	31.69ab	2.33ab	16.67a	74.1	7.6ab	7.8a
Significance Pr > F	*** P < 0.001	*** P < 0.001	*** P < 0.001	--- ---	*** P < 0.001	*** P < 0.001

Means with the same letter are not significantly different according to Duncan's Multiple Range Test. Data for yield, tissue N, NUP, quality, and colour analysed on an average value generated from variables taken over the trial duration. Fertilizer per cent recovery = NUP – NUP from unfertilized control/ applied N *100.Turfgrass quality and colour ratings based on a 1-10 scale with 10=dark green turf, 1=dead/brown turf, and 6=minimally acceptable turf.

Tab. 2: Summary of St. Augustinegrass responses (22/06/2011—17/07/2012).

the untreated control having the expected below acceptable standard turfgrass quality (Table 2). Turfgrass quality and colour was improved by N fertilization and reduced N rates provided statistically-equal turf quality compared to the standard except for the 12 month product which was slightly lower in turf quality than the standard (Table 2). The 6 month duration product provided similar clippings, N content, and N uptake with 18% less N applied (Table 2). Per cent recovery ranged from nearly 40-74% N retention that may provide additional environmental benefit and greater efficiency (Table 2).

Conclusion

Overall N uptake of certain treatments was increased by over 30% while maintaining acceptable turf quality and colour with 25% less N applied thus improving nutrient use efficiency and sustainability of turf.

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Soil phosphorus stability from a Swine-Lagoon Biosolid fertilizer used for roadside grass establishment

Peacock, C.H. and J.P. Gregg

Introduction

The use of biosolids as a soil organic matter amendment can improve soil qualities, particularly soil water retention and nutrient levels (RIGUEIRO-RODRIGUEZ et al., 2000; CHANTIGNY et al., 2002). Phosphorus (P) is important in the establishment and rooting of plants. Increases in fertilizer phosphorus levels do not result in increases in the amount of P recovered from plant material. This indicates that once a plant uptakes sufficient P it will not continue to uptake more P, even if it is available in the soil (EASTON and PETROVIC, 2004). WRIGHT et al. (2005) found that soil extractable P increased at three months after compost addition but found few increases afterward. They also noted a seasonal effect on soil extractable P that they attributed to lower mineralization and plant uptake during winter compared to warmer months.

In some cases, there is little evidence of P leaching 20 years after soil was amended with biosolids, even though P was still five times higher in biosolid amended soils than in untreated soils (HARRISON et al., 1994). Because P is generally attached to soil particles, most P movement comes from sediment eroding from disturbed soils. However, STAHNKE et al. (2013) found that soil extractable P levels increased when turf was fertilized with organic fertilizers at rates to provide adequate N for acceptable turf within three years. Exemptions of organic based P from zero-P fertilization legislation has occurred in several states because it is thought that organic based P is less likely to be lost in leachate or runoff (STAHNKE et al., 2013). While biosolids add organic matter to soil, continued use of biosolids has not been found in some studies to alter the pH level of soils (MEYER et al., 2004). Even several years after biosolid application, pH remained constant and neutral.

One of the most difficult types of turf area to establish is roadside grass. These are usually planted with minimal maintenance receiving only a limited amount of fertilization, infrequent mowing and no supplemental irrigation. Because of concerns over P loss after fertilization, which could create water quality problems, North Carolina Department of Transportation had previously been prohibited from using any type of organic based P containing material for roadside grass establishment.

This study was conducted to evaluate using a material derived from swine-lagoon solids as pre-plant soil incorporated and topdressing fertilizer for roadside grass mix establishment in North Carolina and to determine the stability of the applied phosphorus within the soil profile and its affect on soil pH.

Materials and Methods

This study was conducted at the North Carolina State University Turfgrass Field Lab in Raleigh NC from September 2005 until August 2006. The soil type at this facility is a Cecil sandy loam (fine, kaolinitic, thermic typic Kanhapludult) with 0.5 to 1.0 % organic matter and an initial pH of 4.8 to 5.5. A strip-strip-split block experimental design with three replications was used to test varying rates of SuperSoil as a soil amendment/fertilizer factored over various planting dates. Plots 3.3 x 3.3 m were prepared by first making an application of 2% glyphosate to kill existing vegetation. Dolomitic limestone ($(CaMg)(CO_3)_2$) was then applied at a rate of 2.4 t ha^{-1} based on North Carolina Department of Agriculture (NCDA) recommendations and plots were tilled

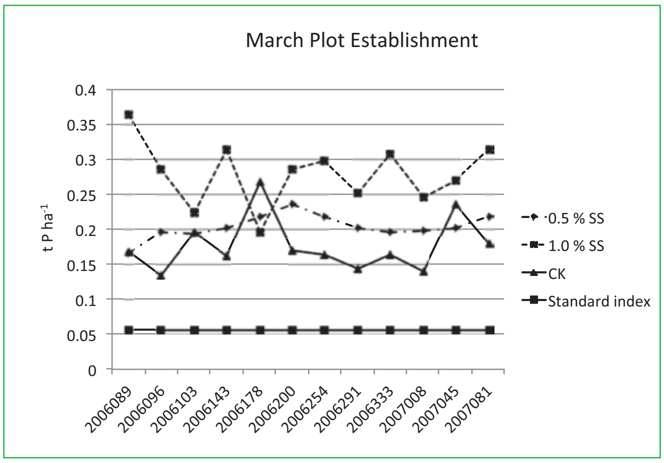

Fig. 1: Soil extractable phosphorus concentrations for plots established in March 2006. The treatment legend indicates the amount of SuperSoil materials incorporated on a volume basis as either 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus optimum index. The Julian date for each collection period is shown on the x-axis.

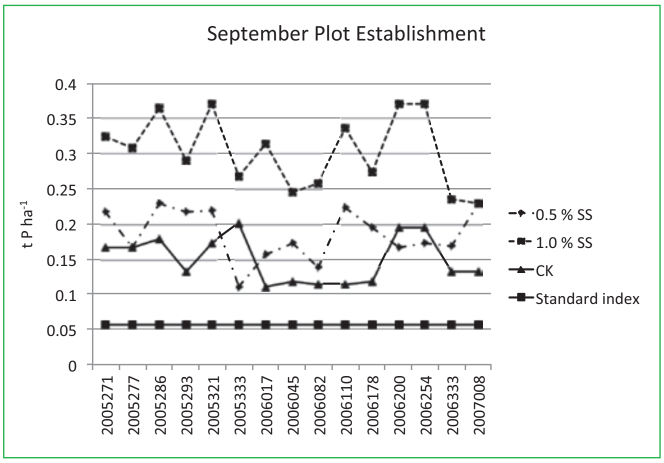

Fig. 2: Soil extractable phosphorus concentrations for plots established in September 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis as 0.5% or 1% and the CK line represents the control, or check, which is an inorganic fertilizer treatment. Phosphorus concentrations are compared to the NCDA suggested phosphorus optimum index. The Julian date for each collection period is shown on the x-axis.

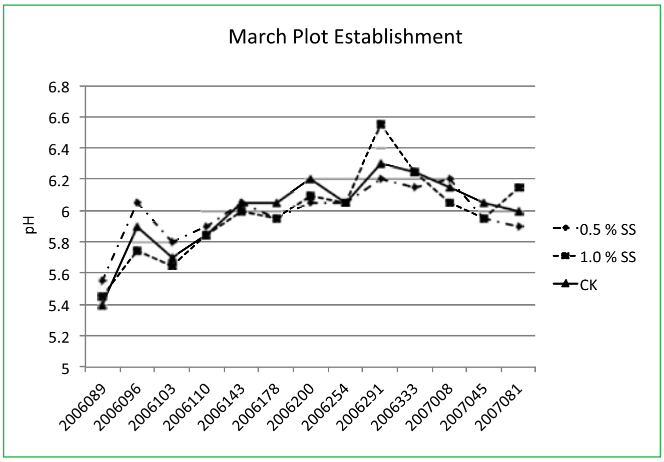

Fig. 3: pH of soil in plots established in March, 2006. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

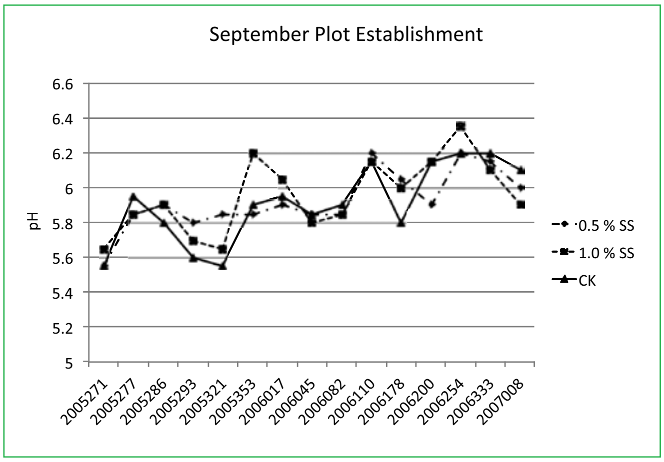

Fig. 4: pH of soil in plots established in September, 2005. The treatment legend indicates the amount of SuperSoil (SS) material incorporated on a volume basis either as 0.5% or 1% and the CK represents the control, or check, which is an inorganic fertilizer treatment. The Julian date for each collection period is shown on the x-axis.

to a 15 cm depth for incorporation of lime and treatment materials. Fertilizers used in this study included SuperSoil (4 N-0.88 P-2.4 K) and the North Carolina Department of Transportation (NCDOT) standard inorganic fertilizer (10 N-8.8 P-16.6 K) that was considered a control consisting of urea, triple superphosphate and potassium chloride. SuperSoil is composed of swine-lagoon sludge aerobically composted with cotton residues and contains < 5% moisture by weight. Fertilizer treatments included the standard check inorganic fertilizer at 0.05 t N ha^{-1} or the organic source SuperSoil at either 0.5% or 1.0% by volume (equivalent to 0.025 and 0.05 t N ha-1, respectively incorporated to a depth of 15 cm. In September of the second growing season, a single topdressing application of each material was made at rates equivalent to 0.025 t N ha^{-1} for the 0.5% v/v SuperSoil incorporated treatment plots and 0.050 t N ha^{-1} for the 1% v/v SuperSoil incorporated and check plots.

Timing factor included six seeding dates (Fall: September, October, November 2005; Spring: March, April, May 2006). Seed was hand raked into the soil and covered with fresh wheat straw. Seed mixtures were based on North Carolina Department Of Transportation (NCDOT) specifications. Plots were seeded at 0.00925 kg m^{-2} with a seed mixture consisting of 63% *Lolium arundinaceum* (tall fescue), 32% *Cynodon dactylon* (bermudagrass) and 5% *Eremochloa ophiuroides* (centipedegrass) by weight and mowed when grass reached a height of 12 cm, usually every five to seven weeks. Plots were maintained at a height of 12 cm by mowing a maximum of five times per year until the centipedegrass component was fully established, upon which the mowing frequency was decreased to two or three times per year.

Three to four soil samples were collected from the first 15 cm of each plot with a soil-sampling tool, the samples were bulked and an aliquot was taken to the NCDA soils lab for nutrient analysis. Percent cover was evaluated monthly and soil samples taken every two to six weeks to analyze for phosphorous and pH.

After the data was reviewed for outlying observations, the data were transformed in Statistical Analysis System using a log transformation for phosphorus concentrations in order to make the data fit a normal curve. A comparison analysis was conducted for three variables as follows: date planted, fertilizer treatment and collection date. Comparative statistics using SAS provided p-values for all the possible combinations of the variables, and an alpha of 0.01 was used to show significance. An LSD was used to compare specific treatments within planting dates.

Results

Phosphorus

There was a change in the soil extractable P level based on the date of establishment. Plots established in March had higher ($P<0.01$) soil extractable P concentrations than all the other dates, except those established in September ($P>0.05$). Over the course of the study, there was no loss in the amount of extractable P found in the soil, irrespective of fertilizer treatment, in plots planted in March, 2006 (Figure 1). Plots treated with 0.5% SuperSoil had a slight increase in soil extractable P concentration ($P=0.0037$) compared to the inorganic standard treatment. Plots treated with 1% SuperSoil had higher P concentrations than either of the other two treatments ($P<0.01$) for all but one sampling date (Julian date 2006178). Plots established in September and amended with 1% SuperSoil had a higher soil extractable P concentration than plots treated with inorganic fertilizer; however, it is not different compared to the plots treated with 0.5% SuperSoil ($p>0.05$) (Figure 2). Over time there was no change in the amount of extractable P found in the soil, irrespective of fertilizer treatment.

pH

There was an increase of soil pH in plots planted in March ($p<0.0001$), September ($p<0.0001$), and October ($p<0.0001$) of 0.6 pH unit. Plots established in November 2005 had a higher pH than the plots established in any other month (data not presented). Soil pH of all three treatments at the March establishment time increased over the course of the study ($p<0.0001$) (Figure 3). However, no differences were found among fertilizer treatments ($p<0.05$). There was an increase in the pH for plots treated with the inorganic fertilizer ($p<0.001$) for the September establishment time, however a change in pH in plots of either of the SuperSoil treatments was not confirmed during the course of the study (Figure 4).

Discussion

Based on the results of this study, soil stability of P was found to be acceptable over the first year after establishment regardless of time of establishment. There was some variability in soil extractable P levels during the change in seasons. This was consistent with what was noted by WRIGHT et al. (2005) and it was probably due to changes in mineralization rates and plant uptake due to changes in soil temperature. CAHILL et al. (2010) note that P fixation in soils that are deficient in P or have low soil pH can occur very rapidly. Results indicated that soil extractable P levels were higher based on percent incorporation of the SuperSoil organic fertilizer. This was in contrast to the findings of WRIGHT et al. (2005) who did not find an increase based on compost application rate. These findings may be due to the type of soil substrate and/or the type of organic material used. In this study soil pH was adjusted with lime prior to establishment, but as mineralization of cations from the organic matter or release from the inorganic starter fertilizer occurred, the pH increased from the initial values as noted in Figures 3 and 4. As stored organic matter pools increase, either from additions of amendments such as was used in this study and/or from root growth and degradation as pH increases, cation exchange capacity increases and available nutrients are stored for plant utilization (BRADY and WEIL, 2008). This was evident by the benefit of the turf performance after establishment. All plots had coverage greater than 90% regardless of fertilizer treatment at eight weeks after seeding (data not presented). This is exceptional compared to similar studies that found at most 50% turf cover in the second growing season of roadside vegetation establishment (BROWN and GORRES, 2011).

Overall, the P and pH results in the soil treated with 0.5% v/v SuperSoil were not different from the soil treated with a standard inorganic fertilizer. However the 1% v/v SuperSoil treatment consistently showed higher P concentrations and higher pH values than the other two treatments. All plots showed an increase in pH over the course of the study, but no fertilizer treatment differences were noted. Based on these results, organic fertilizers such as SuperSoil, even with higher P content relative to N need not pose a greater environmental threat to surface water from P loss for roadside grass establishment.

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How to assess suitability of turf varieties across a wide range of environments in Europe

Lassalvy S., V. Gensollen, M. Straëbler and C. Huyghe

Introduction

The objective of the Turf testing network is to document and thus stimulate genetic progress in turf grasses while giving a similar chance to all breeding companies. The data of the turf evaluation network are used to define the "Sustainable Value for Cultivation and Use" (SVCU) by the "Comité Technique Permanent de la Sélection" (CTPS). These data show a strong genetic progress especially for main cool-season grasses such as Perennial Ryegrass (SAMPOUX *et al.*, 2012, AAMLID and GENSOLLEN, 2013).

Since the early eighties, "Groupe d'Etude et de contrôle des Variétés Et des Semences" (GEVES) publishes every year an agronomic description of the turfgrass varieties which are registered on the French National List. Two synthetic indices – *i.e.* lawn index and sport index – are provided in this description in addition to the SVCU characteristics.

In 2003, a computational method was set to get a variety description independent of the year effect, which makes it possible to compare varieties not sown the same years in the network.

Since 2008, GEVES has extended its national trial network of 8 locations to a European network of 14 sites (HUYGHE AND GENSOLLEN, 2010). The genetic x environment (G x E) interactions met in this new network (LASSALVY *et al.*, 2012) are partly taken into account with the network shared into *a priori* bioclimatic zones, as shown on the European map (Figure 1).

The "Groupement National Interprofessionnel des Semences et plants" (GNIS) and the GEVES manage a project of a website about turf varieties description, which displays the varieties characteristics for comparisons. Regionalized information, specific to each bioclimatic zone, should also be available in this new website.

Materials and Methods

Every year, new candidate varieties are sown in the 14 locations following a random complete block design with 3 replications. The trials last 3 years and their results are summarized to provide the SVCU values of the varieties. Those data are used by the CTPS for SVCU decisions, and to calculate an independent and reliable description of the varieties for the benefit of the end-users.

GEVES publishes an annual report about 14 turfgrass species, such as perennial ryegrass (*Lolium perenne*), tall fescue (*Festuca arundinacea*), slender creeping red fescue (*Festuca rubra trichophylla*), chewing red fescue (*Festuca rubra commutata*) and strong creeping red fescue (*Festuca rubra rubra*). The report describes 15 SVCU agronomic characteristics (*e.g.* general merit, shoot density, thinness of leaves, diseases resistance).

To compute a reliable description, SVCU values of several consecutive years of testing are considered. A two-step computational method is then applied to each agronomic trait to get a description independent from the yearly results, that is to say, make it possible to compare varieties sown and tested in different years.

In the first step of the method, the data of the agronomic trait of interest are compiled in an incomplete variety x trial table. Only the varieties observed for at least two trials - called 'bridge varieties' - are considered. An additive "variety + trial" ANOVA model is fitted to these data to get the 'bridge varieties' and trials effects. These effects are used to compute the fitted values of the model and to extrapolate the variety x trial missing data as the sum of the corresponding variety and trial effects. A complete variety x trial table is obtained from these calculated values. The 'bridge varieties' means and the trials means are calculated as the rows and columns means of this last table whose overall mean is also made.

The second step of the method combines the previous results to the varieties data and provides the description value of the varieties as follows:

- For a 'bridge variety', the description value is its 'bridge variety' mean.
- For a registered variety only observed for one trial, the description value is:
  Description value = SVCU value / corresponding trial mean * overall mean.

Two additional indices are finally calculated. They consist in a weighted mean

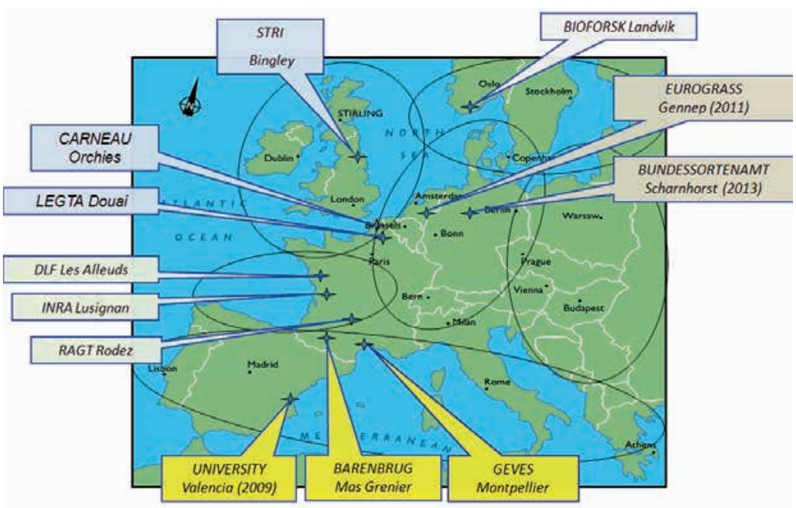

Fig. 1: Bioclimatic zones in Europe and turf testing locations.

Characteristics	Weights	
	Lawns Index	Sport index
General aesthetic qualities	2	1
Summer aesthetic qualities	1	1
Winter aesthetic qualities	1	1
Wear tolerance	3	
Winter wear tolerance		5
Shoot density	1	2
Thinness of leaves	1	
Persistency	1	

Tab. 1: Lawns and sport indexes weights.

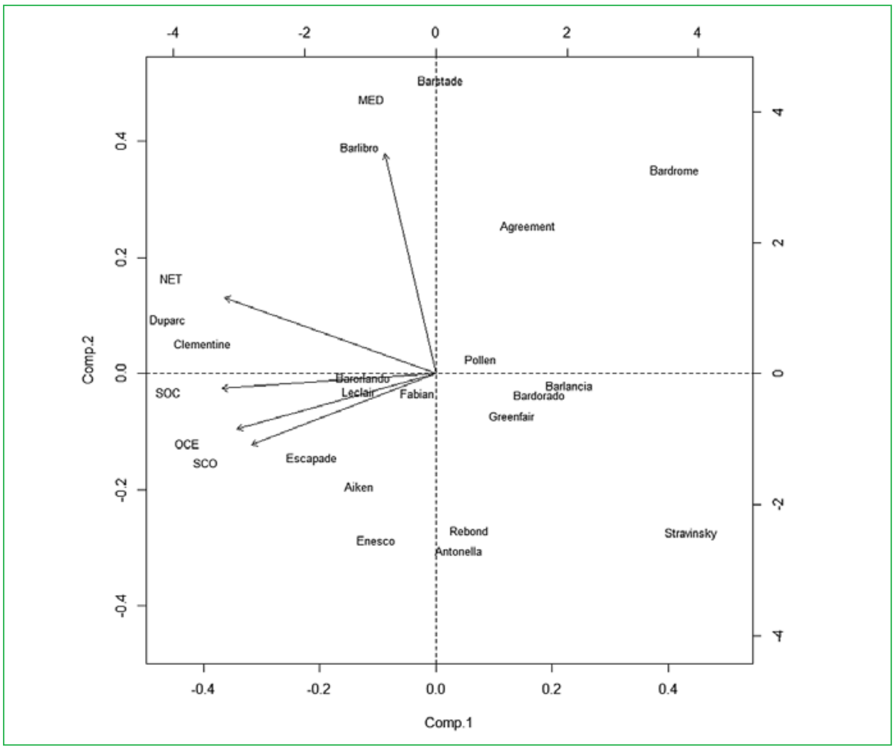

Fig. 2: First plane of the five indices PCA.

of the characteristics that CTPS members consider the most relevant for the corresponding use: for lawns with a moderate wear or for sport pitches, with a more intensive wear during sport seasons. In this paper we will describe the lawn index (Table 1).

The lawn index was calculated for 19 varieties of perennial ryegrass on the whole network (**NET**) and 4 climatic zones: the oceanic zone (**OCE**), the semi-oceanic (**SOC**), the semi-continental (**SCO**) and the Mediterranean (**MED**) one. A principal component analysis (**PCA**) of the five indices was then performed.

Results and Discussion

The first PCA plane explained 73% of the total variance (Figure 2). The PCA showed that the Mediterranean zone behaved differently from the three other zones, which are highly correlated to each other. This analysis shows that the bioclimatic zones indices bring different and additional information to the network index and could enrich the variety description.

Conclusion

This paper explained how GEVES develops a description based on official SVCU data to get sound and comparable values for the registered varieties even if they are not sown during the same years of trials. Moreover, the European network, subdivided in bioclimatic zones, makes it possible to compute regional indices, which bring additional information to the network index, and could be interesting for breeders to improve their selection work and for end-users to choose the most fitted turf varieties. The current description database is available to the general public through the Internet on http://turfgrass-list.org. A French version is also available on http://choixdugazon.org.

Acknowledgement

Thank to Corinne BERTHUIT for calculating the different indices.

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Comparison of the germination rates at low temperature of some recent annual and perennial ryegrass varieties

Lung-Tsakos, J. and G. Lung

Introduction

Fast germinating seed blends are indispensable for a quick recovery of sport turf areas especially during the cold season. Therefore an important characteristic for these blends is the ability to germinate quickly at low soil temperatures and bring the turf back to playability in a very short time.

Some time ago Barenbrug introduced the 'SOS' Blend (Super Over Seeding) to the market. This blend contains the Annual ryegrass *Lolium multiflorum var. Westerwoldicum*. This ryegrass has the ability to germinate quickly at 6 °C and rapidly build up a dense turf canopy. Because *Lolium multiflorum var. Westerwoldicum* is an Annual Ryegrass and has to be overseeded yearly, the question was raised about how fast the actual diploid and tetraploid Perennial Ryegrass varieties germinate compared to the two *Lolium multiflorum var. Westerwoldicum* varieties. It is only rumoured that especially the tetraploid Ryegrass varieties germinate at low temperatures as well. Rapidly germinating Perennial Ryegrass would be very advantageous because once established as perennial in the turf, yearly overseeding would become less indispensable.

This research project compared some recent varieties of diploid and tetraploid Perennial Ryegrass with two varieties of Annual Ryegrass – *Lolium multiflorum var. Westerwoldicum* ('Axcella' I Lmw and 'Axcella' II Lmw). For these tests, Barenbrug did not provide the Annual Ryegrass varieties present in the 'SOS' blend so the 'SOS' Blend was used as such.

Materials and Methods

The trials were carried out in a germination facility at the two controlled temperatures of 10 °C and 5 °C (Table 1). The soil substrate was a mix of sand and topsoil (80:20), which represents the common practice, and is also used in demonstration plots at the DemoGolf Exhibition in Eisenach, Germany.

The trials took place in culture dishes containing either a layer of 2 cm of soil mix alone or the same soil mix and a layer of paper. In all the dishes water was applied at the same rate to provide enough moisture for the germination process. Each dish was covered with a lid in order to avoid the loss of moisture. Each dish contained 50 seeds, each variety was repeated twice in separate dishes. The seeds placed over the soil substrate were slightly pressed in, in order to provide a good contact with the substrate.

After the beginning of the trial all dishes were controlled daily and the germinated seeds counted. The seeds were considered germinated when the radicle was visible. The trial continued until at least 80% of all seeds of all varieties germinated.

Table 2. reports the number of varieties of the Ryegrass species on trial.

Results

As expected the two Annual Ryegrass – *L. multiflorum* varieties 'Axcella' I and II – showed an excellent germination rate at both temperatures (Figure A, B, C). The three tetraploid (4n) Perennial Ryegrass (Lp) varieties showed different results at the two temperatures. 'Double' (Lp 4n) germination rate, at both 10 °C and 5 °C, was not much slower than the Annual ryegrass – 'Axcella' I and II. The other two tetraploid Perennial Ryegrass varieties showed a slower germination at 5 °C and did not germinate much faster than most of the diploid (2n) Perennial ryegrass varieties.

Unexpected was to find that two diploid Perennial Ryegrass varieties (Barorlando and Barlennium) showed (Figure B) similar and good germination rates at 5 °C as both the Annual Ryegrass 'Axcella' I and II varieties.

The most important differences between the Ryegrass species appeared at 5 °C. Most of the diploid Perennial ryegrass varieties failed to germinate at 5 °C and this is why Figure A and B only show few of the diploid Perennial Ryegrass varieties.

The differences at 10 °C appeared more gradually. Some diploid Perennial Ryegrass varieties showed an extremely low germination rate already at 10 °C (Figure C): 'Vesuvius', 'Barsignum', 'Concerto', 'Lorettanova', 'Bareuro', 'Dickens'. The other varieties were only partially slower than the Annual Ryegrass 'Axcella' I and II, and performed as well as the fast germinating tetraploid Perennial Ryegrass variety 'Double' (Figure C).

No eminent difference was found in the germination rate at 5 °C after 25 days (Figure A), between the 'SOS' blend, the Lp 4n 'Double' and the two Annual Ryegrass 'Axcella'. The variety 'Double' performed on the soil substrate as well as the Annual ryegrass-varieties.

Discussion

These germination tests showed that the tetraploid Perennial Ryegrass vari-

	Temperature level	
	10 °C	5 °C
Day/night rhythm	12 h day/12 h night	12 h day/12 h night
Substrate	Soil mix	Soil mix + paper

Tab. 1: Germination conditions.

Lolium multiflorum var. Westerwoldicum (annual)	*Lolium perenne*	
	Diploid (2n)	Tetraploid (4n)
2 varieties 1 Blend 'SOS'	31 varieties	3 varieties

Tab. 2: Number of varieties of the different Ryegrass species.

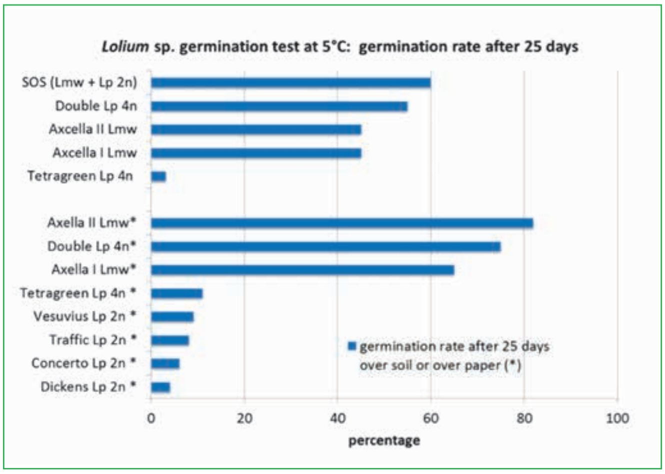

Figure A

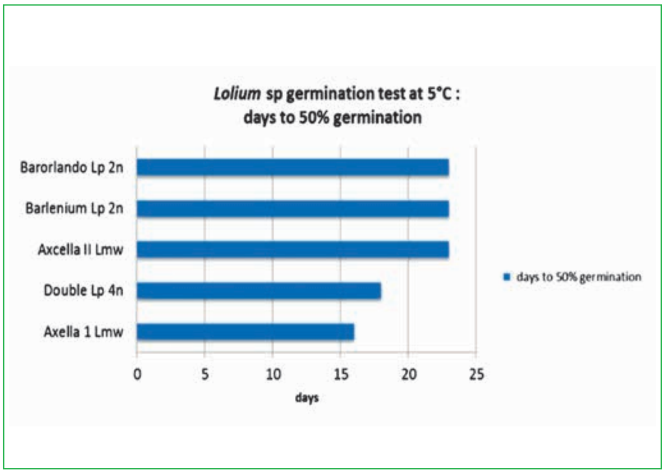

Figure B

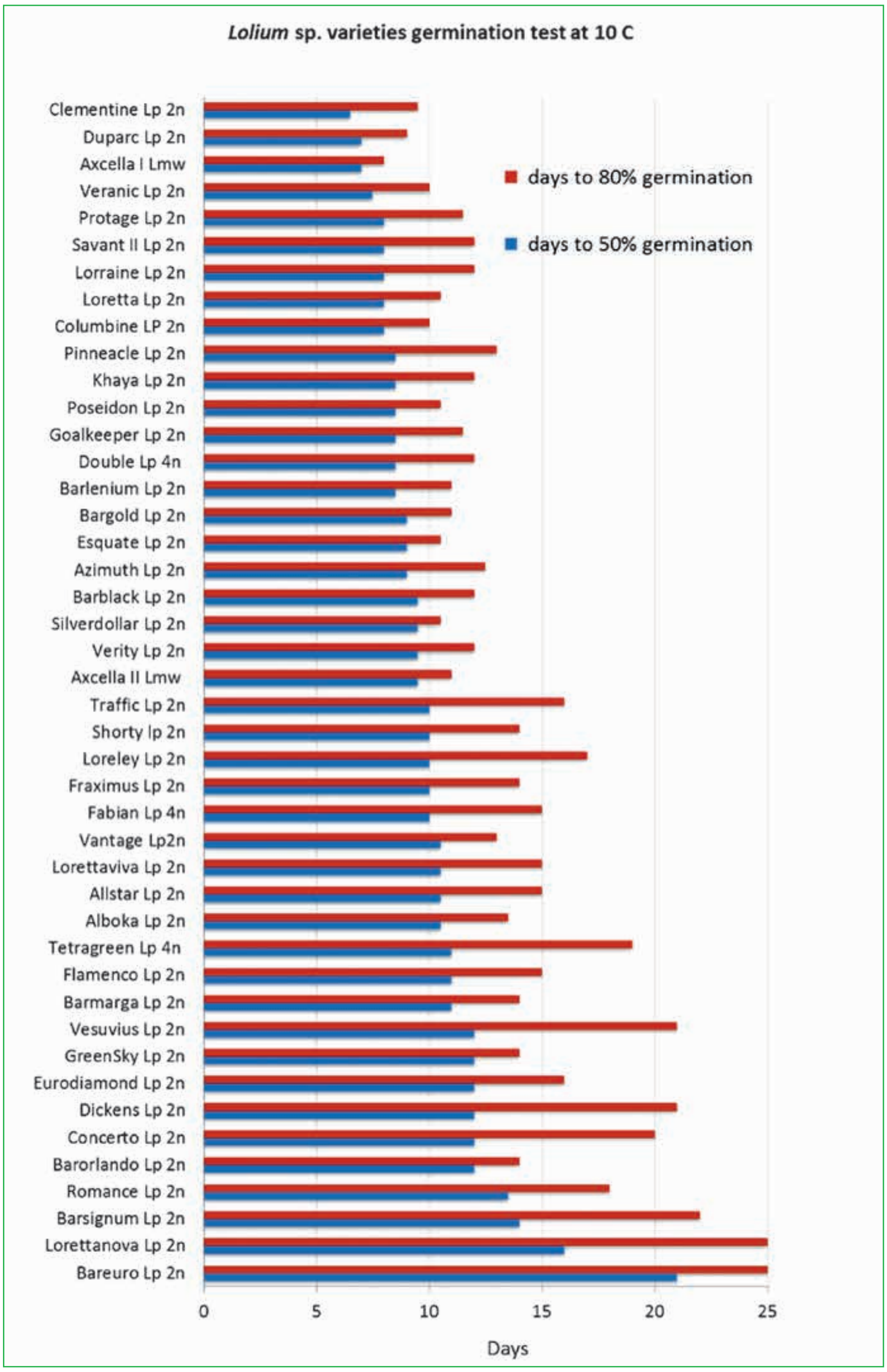

Figure C

ety 'Double' at low temperatures can keep its germination pace similar to the Annual ryegrass – *L. multiflorum* varieties 'Axcella' I and II. 'Double' was only slightly slower than the 'SOS' blend. Barorlando and Barlenio, two diploid Perennial Ryegrass varieties, also showed very good germination characteristics at 5 °C.

This raises the question if Annual Ryegrass varieties are even needed for the overseeding of sport turf areas at low temperatures if Perennial Ryegrass varieties (diploid + tetraploid) show approximately the same favourable characteristics.

The advantage of Perennial Ryegrass is its persistence in the turf canopy for a longer period. Furthermore traffic tolerance of Perennial Ryegrass is believed to be higher (statement of STRI, verbal communication from DLF).

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G. Karaiskakis stadium ten years after: Assessing the irrigation system impacts on turf quality

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Introduction

Irrigation efficiency and uniformity are of critical importance for water conservation of high quality turfgrass stands. In sport fields, where is well documented that playing quality is strongly correlated with the management practices, water input is a major issue for turfgrass growth and quality (MCCARTY, 2005). According to CARROW et al. (2010) among the components of site specific turfgrass water conservation programs are the irrigation/water audit, the efficiency of both, irrigation system design, scheduling and operation, along with the needed irrigation devices.

Football fields are usually located in urban or suburban areas and the use of potable water for irrigation needs is still a fact. New football stadiums though, are designed as multifunctional buildings with a profit earning purpose, aiming primarily to provide comfort to spectators (SZUCS et al., 2009). Being considered as semi-outdoor spaces (SZUCS et al., 2009) by the architects and the constructors, turfgrass managers may have to confront with diverse management conditions such as wind velocity, solar radiation and thermal conditions, provoked by the bowl design and roof construction materials. Georgios Karaiskakis stadium is classified by UEFA as a 5-star football stadium. Aim of the present case study was to audit and depict the irrigation system's performance and uniformity ten years after the installation and the effects on turf visual quality.

Materials and Methods

The study was performed in the turfgrass field of Karaiskakis stadium, located in Peiraeus Greece (37°56′46.21″N 23°39′52.33″E). The football arena is near the Saronic Gulf, being subjected to Mediterranean climatic conditions. The field was sodded in 2007 with 'Tifway 419' and over-seeded with Kentucky bluegrass in order to achieve the required turf properties, including fast recovery, throughout the year.

The field size is 120 x 80 m, while the net playing area is sized by 105 x 68 m. The substrate profile is a loamy sand with 81.8% sand, 12% silt and 6.2% clay and the turfgrass is irrigated with potable water. The irrigation system consists of 7 irrigation cycles with a system of sprinklers Rain Bird 8005 arranged in a 20 x 20 m quadrate shape, and controlled by a Rain Bird ESP-LX controller. Each one of the nozzles provides a mean irrigation height of 7.67 mm during its operation (20 minutes) at its maximum capacity.

For the purposes of the monitoring the field was divided to 11 areas (A-K field areas) following the sprinklers arrangement and each one on a 10 x 10 m grid (plot 1-8). The visual quality, using a 1 to 9 scale (where 1=dead, 7=minimum acceptable, 9=perfect), was evaluated by two researchers, on July 16, 18, 20, 23 2012, at 10 am and 1pm; the mean value of the two measurements of each plot was derived, and the mean weekly visual quality of each area assessments was calculated.

For the assessment of the irrigation system's performance and uniformity, catch-can method was used. The measured water volumes were analyzed via GIS software and a map of irrigation equipotential lines depicting the uniformity of the applied irrigation was delivered, showing the uniformity of the applied irrigation along the field.

Analysis of variance was performed to all visual quality data among areas for 10 am and 1 pm weekly assessments with STATGRAPHICS Centurion XV and the means were compared using the least significant difference LSD test at the 0.05 probability level. A t-Test analysis was used to find if any significant differences in each area between the two above mentioned visual quality assessments were recorded.

Results

The field's overall impression concerning visual quality of the turfgrass was almost perfect at 10 am. The mean weekly visual quality was higher than 8 in all the eleven field areas. Statistical differences though were observed among them, with A and B having the lower visual quality namely 8.36 and 8.33 (Table 1).

After midday a deterioration of the visual quality was observed in all the

Area	10am	1pm
A	8.36 c ± 0.06 **	7.56 a ± 0.20
B	8.33 c ± 0.18 *	7.59 a ± 0.25
C	8.79 ab ± 0.10 **	7.92 a ± 0.20
D	8.83 a ± 0.12 ***	7.81 a ± 0.14
E	8.80 a ± 0.09 ***	7.81 a ± 0.14
F	8.73 ab ± 0.14 ***	7.72 a ± 0.15
G	8.86 a ± 0.08 ***	7.86 a ± 0.15
H	8.62 abc ± 0.14 **	7.58 a ± 0.21
I	8.50 bc ± 0.00 **	7.50 a ± 0.19
J	8.89 a ± 0.08 ***	7.70 a ± 0.18
K	8.73 ab ± 0.11 ***	7.48 a ± 0.11

§ Mean values of the columns followed by different letters denote statistical differences at $P \leq 0.05$, among areas. The t-Test analysis among columns is represented by asterisks (*= $P \leq 0.05$, **= $P \leq 0.01$, ***= $P \leq 0.001$)

Tab. 1: Mean visual quality (1-9, 7=minimum acceptable) of the four assessments of each irrigation station/field area at 10am and 1pm (mean ± s.e.).

Fig. 1: Aerial photo of Georgios Karaiskakis football arena at 23 June 2012 (Image © 2013 Digital Globe).

field areas, without recording though any differences among them. A great decrease in visual quality was observed at A, B, I and K areas located at the longest sides of the field, getting a rating of 7.56, 7.59, 7.50 and 7.48 respectively. In these areas leaf firing was observed at several plots. The difference between the morning and the noon assessments was found to be statistically significant (Table 1). As it can be observed by the aerial photo in Figure 1 (Image © 2013 Digital Globe) taken at 23 June 2012, there were differences on the ground cover of the field areas following the sprinklers pattern.

The map of irrigation equipotential lines depicted with details the applied water quantity in the eleven areas. It was recorded a non uniform irrigation among the plots which may resulted to the deterioration of visual quality after midday and to the differences to the field's ground cover a month earlier.

Discussion

The applied water uniformity had a major impact on the turf quality and the fact is confirmed by the visual assessment of the aerial photo. Even though bermudagrasses are well adapted to hot and dry conditions, improper water application may reduce the acceptable quality when low mowing is applied (BALDWIN et al., 2006). According to MCKENNEY and ZARTMAN (1997), the controlling factor for turfgrass production and quality is the irrigation quantity and not the species itself. The observed spots with leaf firing after midday, when the maximum of temperature occurred, indicate an irrigation system malfunction. As it was derived from the map of irrigation equipotential lines, the plots that were receiving less water quantity scored the lowest visual quality rating especially at 1 pm. In addition the arena bowl design creates shaded areas, where the applied irrigation volume seems to be in excess. In conclusion, both a redesign of the irrigation system and a rescheduling are considered essential in order to improve the water management and the quality of the bermudagrass during summer months.

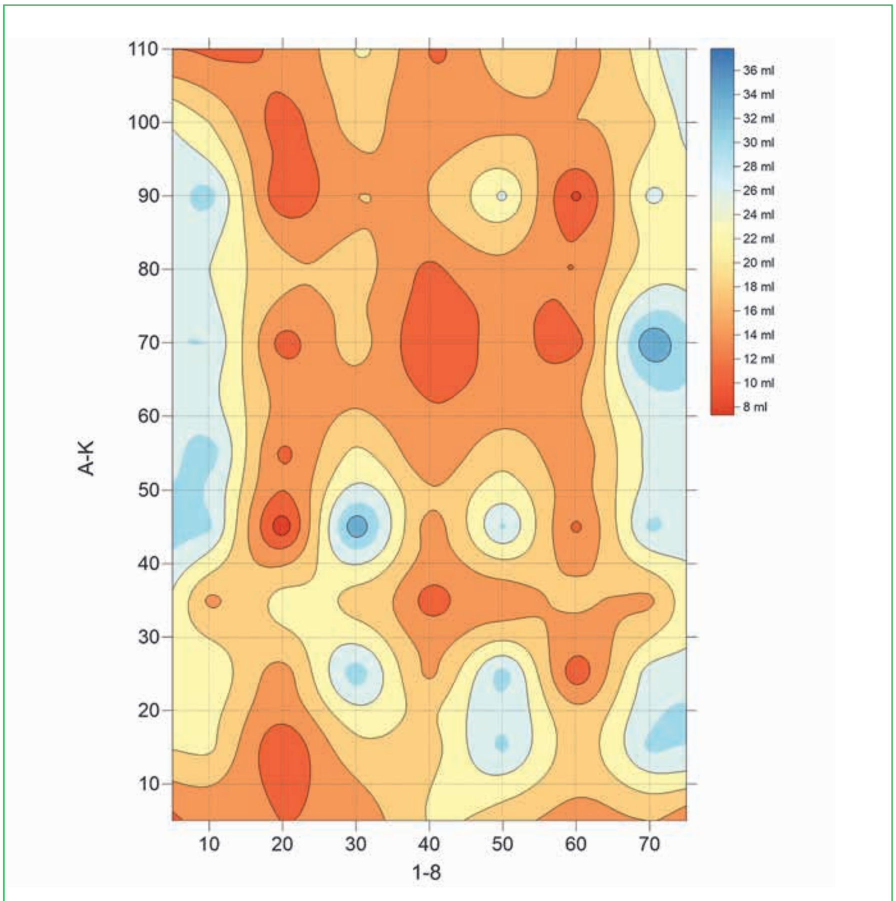

Fig. 2: Map of irrigation equipotential lines derived from the on site catch-can measurements taken at 24th July 2012.

Acknowledgments

The performed on site field evaluation was under the supervision of GREEN PARK Ltd. The authors would like to thank the company for all the information on the field and the applied management techniques.

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Detection of turf grass diseases by DNA profiling of pathogens

Pogner C., D. Bandian, M. Gorfer and J. Strauss

Introduction

Fungal infections of turf grass are one of the biggest problems on golf courses and other sports fields. As the density of golf courses, and therefore the competition between plants, and the demands of players are high, grass health becomes a high priority in management.

Daily mechanical treatment and the influence of weather are highly stressful for the plants and can favour the spread of fungal infections. Mostly turf diseases like fungal infections are not recognised until discoloured, dead or missing grass is detected. The symptoms of different diseases are very similar to each other and the distinction is challenging, even for a skilled green keeper.

To prevent and effectively control turf grass diseases and to adapt the management, it is important to know which pathogen is causing problems, ideally before the appearance of symptoms.

Current methods for fungal pathogen detection are often not quantitative and cannot correctly identify multiple infections. New DNA analyses are able to accurately identify and quantify all active and inactive pathogens from grass samples.

DNA Analyses

Detection of turf diseases by DNA profiling is an established analysis. The Austrian Institute of Technology (AIT) has advanced the technique to detect pathogens in turf grass and root samples so that it is possible to identify pathogens, determine their quantity and make it possible to estimate their infection pressure.

The grass and root samples are collected by the green keeper, according to instructions by the laboratory and are sent there for analyses. At the AIT laboratories the DNA of the samples is extracted and purified. In this DNA-solution the DNA of the grasses and the ones of the occurring pathogens is present.

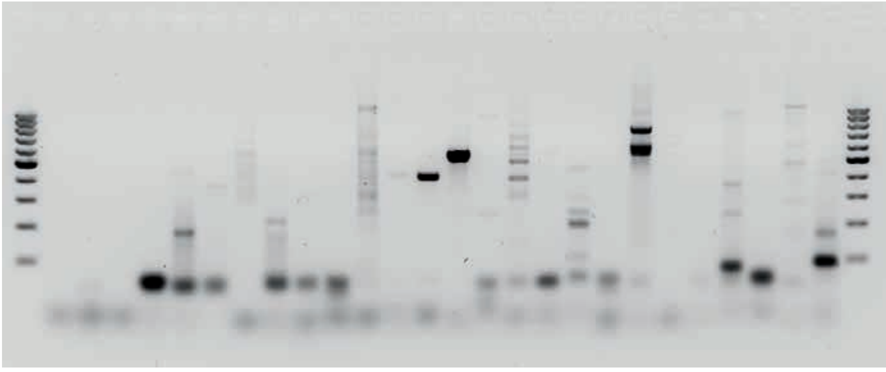

Fig. 1: Example of electrophoresis gel of a fungal turf grass pathogen analysis, used for visualisation after PCR.

The new screening for fungal pathogens uses an advanced polymerase chain reaction (PCR) technique where simultaneous detection and quantification of more than 25 pathogens is carried out.

RasenCheck

The RasenCheck uses an advanced PCR technique to test turf grass samples for 30 fungal turf grass pathogens. Either individual samples are sent in, if symptoms of a disease are found and cannot be attributed to a pathogen, or green keepers and golf courses participate in the RasenCheck monitoring project where greens are monitored and sampled periodically over the whole season (8 months).

The RasenCheck monitoring pilot project started 2013 with 5 participating golf courses in Austria. The occurrence of fungal pathogens was monitored over a period of 15 weeks. The DNA Analyses were carried out with standard PCR method; the new technique will be available in 2014.

Nearly all pathogens occurred at least once over the monitoring period. The infections were mostly multiple infections with more than one pathogen. Due to the weather patterns, in 2013 mostly anthracnose (*Colletotrichum graminis*) and leaf bleach (*Drechslera sp.* and several other pathogens) where detected, take-all-patch (*Gaeumannomyces graminis*) and snow mold (*Microdochium nivale*) have also been detected more often.

A correlation between weather conditions (heat and rain) and the occurrence of diseases could be observed.

In 2014 the RasenCheck monitoring project will be extended. The monitoring period covers 25 weeks of sampling, 2 in spring, 22 from June to October and 1 in November. The analyses are carried out with the advanced PCR technique that can also quantify the occurring pathogens.

Additionally, weather conditions of the different regions (macroclimate), of the participating golf clubs (mesoclimate) and of the sample sites/greens (microclimate) are monitored closely during the project period.

The goal of the RasenCheck monitoring is the identification of pathogens before symptoms occur. Additionally to active pathogens, which have already infected the plant, inactive pathogens can be detected and the risk of infections can be predicted.

Due to this information, pathogens can be controlled more efficiently, preventative actions against future infections can be taken, the use of chemical plant protection products can be reduced and the management protocols can be adjusted.

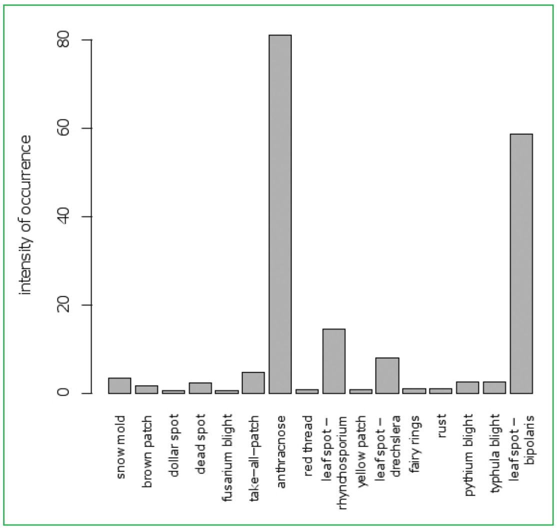

Fig. 2: Number of turf grass disease occurrences (on all participating golf courses) during the project RasenCheck in 2013.

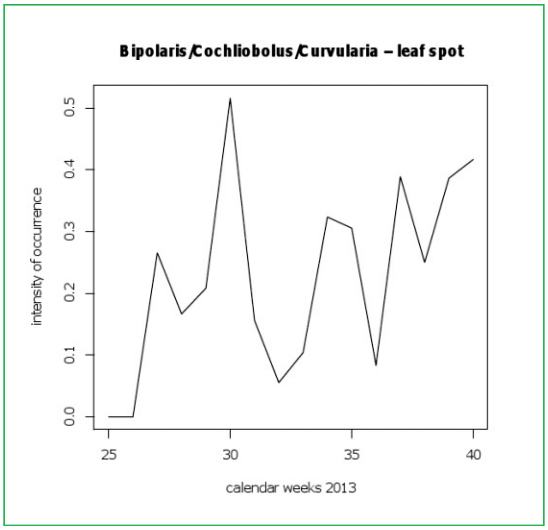

Fig. 3: development of leaf blight during the project period of RasenCheck 2013.

Prospect

As it was shown in 2013, fungal turf grass pathogens are influenced by weather conditions. The results of the weather and pathogens monitoring during 2014 will be used to develop a modelling tool for the prediction of the pathogens manifestations based on the infection pressure and the weather forecast.

By knowing which pathogen is present on the greens (due to the RasenCheck monitoring) and by the modelling tool of the pathogen's spread, green keepers should be able to adjust their management measures to prevent extensive infections on greens, and therefore control pathogens more efficiently and reduce the use of chemical products for plant protection.

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Fungicides for control of *Microdochium nivale* and *Typhula incarnata*

Aamlid, T.S., T. Espevig, W.M. Waalen and T. Pettersen

Introduction

The turfgrass pathogens resulting in the greatest economic losses in the Nordic countries are *Microdochioum nivale* (Fr.) Samuels and Hallett and *Typhula incarnata* (Lasch ex. Fr.) causing pink and gray snow mold, respectively. *M. nivale* also causes microdochium patch (formerly 'fusarium patch') under cool and wet conditions during the growing season, especially in the fall. (ÅRSVOLL, 1973).

A few strobilurines or demethylation inhibitors (DMIs) are currently labelled for snow mold control in the Nordic countries. Resistance to these fungicides has been reported for other pathogens, but so far not for *M. nivale* or *T. incarnata* (LATIN, 2011). The risk for *M. nivale* to develop resistance is, however, considered high (LATIN, 2011), and the Scandinavian labels for stobilurines and DMIs therefore prescribe a maximum of two to four applications per year. Classical contact fungicides with multiple modes of action, such as chlorothalonil or PCNB, are not available for turfgrass use in the Nordic countries, and iprodione, which was the most widely used fungicide until a few years ago, has also been withdrawn from the market. For this reason, Scandinavian turfgrass managers have been looking for a 'contact' fungicide that can be applied shortly before snow fall in rotation with the 'systemic' fungicides.

Our objective was to evaluate the efficacy of Banner MAXX, Headway and Medallion, turfgrass formulations of propiconazole, azoxystrobin + propiconazole and fludioxonil, respectively, for the control on *M. nivale* and *T. incarnata* on Scandinavian golf courses. Although propiconazole and azoxystrobin are classified as acropetal penetrants and fludioxonil as a local penetrant (LATIN, 2011), we will, for the purpose of this paper, refer to Banner MAXX and Headway as 'systemic' and Medallion as 'contact' fungicides, respectively.

Materials and Methods

The material comprises one trial from October 2011 to May 2012 on an experimental green with a turf cover of 100 % annual bluegrass (*Poa annua*) at the Bioforsk Turfgrass Research Center Landvik, SE Norway and two trials from October 2012 to May 2013 on greens with 100 % creeping bentgrass (*Agrostis stolonifera*) or 85 % annual bluegrass + 15 % creeping bentgrass at Arendal GC, SE Norway and Österåker GC, Stockholm, Sweden, respectively. Fungicides were applied up to four times in October and November in a water volume of 250 L ha^{-1}. Medallion, Banner MAXX and Headway were all applied at a rate of 3 L ha^{-1} corresponding to 375 g a.i. fludioxonil ha^{-1}, 468 g a.i. propiconazole ha^{-1} and 187.5 g a.i. azoxystrobin + 312 g a.i. propiconazole ha^{-1}, respectively. In 2012-13 Banner MAXX was also applied in early spring immediately after snow melt in some of the treatments. The percentage of plot area affected by disease was assessed at regular intervals before, during (in the absence of snow cover) and after winter and turfgrass general impression was assessed in spring. The identity of winter diseases was verified by samples sent to Bioforsk Turfgrass Diagnostic Lab. All trials were established according to randomized complete block designs and results were analysed by ANOVA.

The experimental season 2011-12 was mild with higher-than-normal temperatures during the entire trial period at Landvik. Snow covered the green from 21 Jan. to 23 Feb only, and March had record-high temperatures resulting in an early start of the growing season. The experimental season 2012-13 was much colder and the trials at Arendal GK and Österåker GK were covered with snow from 2 Dec. to 21 Apr. and from 29 Nov. to 10 Apr., respectively.

Results

In the 2011-12 trial on the annual bluegrass green at Bioforsk Landvik, 1-3 % of the green surface had already developed microdochium patches by the first fungicide application on 13 Oct. (Table 1). Both Medallion and Headway controlled this infection and there was no difference in the efficacy of the two products. In contrast, *M. nivale* continued to develop on unsprayed plots and reached a maximum of 27.5 % on 28 Feb. after about one month of snow cover. At the following assessments on 29 Mar. and 30 Apr. only treatment 5 that had received one application of Headway in October plus two applications of Medallion in November were completely without disease, and these

		Microdochium nivale % of plot area						General impression (1-9, 9 is best)
Treatment no. / Fungicide on 13 Oct. + 2 Nov. + 28 Nov.		11 Oct.	15 Nov.	9 Dec.	28 Feb.	29 Mar.	30 Apr.	30 Apr.
1	0 + 0 + 0 (unsprayed control)	2.7	9.2	22.0	27.5	23.3	18.8	2.3
2	Medallion + 0 + Medallion	2.0	0.7	0.3	1.7	1.3	0.3	5.9
3	Headway + 0 + Medallion	2.2	1.2	1.0	1.5	1.5	0.9	6.3
4	Headway + 0 + Headway	1.3	0.8	0.5	1.5	1.8	1.2	5.8
5	Headway + Medallion + Medallion	1.5	0.3	0.0	0.3	0.0	0.0	7.2
Sign.[1]		ns	***	***	***	***	***	***
$LSD_{0.05}$		-	2.4	7.5	7.4	6.7	4.9	1.4

1 ***: $P≤0.001$, **: $P≤0.01$, *: $P≤0.05$, (*): $P≤0.10$; ns: $P>0.10$

Tab. 1: Percentage of the plot area infected by *Microdochium nivale* on various dates and turfgrass general impression in spring on annual bluegrass green at Bioforsk Landvik 2011-12.

Treatment no	Application date					*T. incarnata* % of plot area		General impression (1-9, 9 is best)
	10 Oct.	24 Oct.	14 Nov.	28 Nov.	24 Apr.	24 Apr.	7 May	7 May
1	Unsprayed control					5.3	8.7	2.5
2	Banner M.			Medallion		0.3	4.3	3.7
3	Banner M.		Medallion	Medallion		0.0	2.3	5.0
4	Banner M.	Medallion	Medallion	Medallion		0.0	1.7	5.8
5	Headway		Medallion	Medallion		0.1	1.7	5.2
6	Banner M.	Banner M.	Medallion	Medallion		0.0	2.3	4.7
7					Banner M.	4.7	6.0	3.2
8	Banner M.		Medallion	Medallion	Banner M.	0.1	3.7	4.5
Sign.[1]						***	***	***
$LSD_{0.05}$						3.3	3.0	1.3

1 ***: *P*≤0.001, **: *P*≤0.01, *: *P*≤0.05, (*): *P*≤0.10; ns: *P*>0.10

Tab. 2: Effect of fungicide applications in autumn and spring on percentage of plot area infected by *Typhula incarnata* at snow melt and turfgrass general impression two weeks after snow melt on a creeping bentgrass green at Arendal GC, 2012-13.

Treatment no	Application date			*M. nivale*, % of plot area	Gen. impression (1-9, 9 is best)
	31 Oct.	16 Nov.	25 Apr.	11 Apr.	14 May
1	Unsprayed control			21.2	7.0
2	Banner M.			4.5	7.5
3	Banner M.	Medallion		5.3	7.0
4	Headway			4.0	7.3
5	Banner M.	Banner M.		4.0	7.7
6			Banner M.	13.7	7.7
7	Banner M.		Banner M.	7.0	7.3
Sign.[1]				***	Ns
$LSD_{0.05}$				8.9	–

1 ***: *P*≤0.001, **: *P*≤0.01, *: *P*≤0.05, (*): *P*≤0.10; ns: *P*>0.10

Tab. 3: Effect of fungicide applications in autumn and spring on percentage of plot area infected by *Microdochium nivale* at snow melt and turfgrass general impression one month after snow melt on green dominated by annual bluegrass at Österåker GC, 2012-13.

plots also gave the best general impression.

In 2012-13, the creeping bentgrass green at Arendal GC showed no symptoms of disease in autumn (not shown). At snow melt in spring, there was still no symptoms of *M. nivale*, but *T. incarnata* covered approximately 5 % of the area on unsprayed plots (Table 2). From the table it also appears that the percentage of plot area infected by disease increased from the first to the second assessment in spring, but this is probably an artefact as different persons assessed the plots on the two dates. Irrespective of this, treatment 2 that had received only one application of Banner MAXX plus one application of Medallion seven weeks later tended to have slightly more disease and significantly lower general impression than the treatments that had received three or four fungicide applications. Application of Banner MAXX after snow melt tended to improve the general impression (recovery from disease) on plots that had not been sprayed with fungicides in autumn but had no positive effect on plots where *T. incarnata* was already controlled by fungicide applications in autumn. The highest general impression in spring was found on plots that had been sprayed four times in autumn, first with Banner MAXX and then with Medallion at two to three week intervals until snow cover.

The annual bluegrass trial at Österåker GC in 2012-13 showed no diseases before winter At snow melt in spring, *M. nivale* covered 14-21 % of the plot area on unsprayed plots (treatments 1 and 6) versus 4-7 % on plots that had been sprayed once or twice in late autumn (Table 3). Banner MAXX at snow melt had no significant effect on turfgrass general impression one month later.

Discussion

Reduction in pesticide use is a political goal in Scandinavia as in other parts of Europe (EU 2009). It is therefore a highly relevant question what is the minimum number of applications and rates needed for adequate control of *M. nivale* or *T. incarnata*. The trial at Österåker GC in 2012-13 showed that one rather late application of Banner MAXX at 3 L = 468 g a.i. propiconazole ha^{-1} reduced pink snow mold in spring by an average of 67 % (average of treatments 2 and 7 vs. average of treatments 1 and 6). This level of control is better than in the northern United States where JUNG et al. (2008) reported only 30-35 % reduction in disease severity of *M. nivale* after one application of Banner MAXX at 12.8 L ha^{-1}, i.e. more than four times the rate used in our trials. At Arendal GC, the control of *T. incarnata* with only one application of Banner MAXX plus one application of Medallion was also better than in similar evaluations of propiconazole and fludioxonil in North America (JOHNSON & GOLOB, 2003; JUNG et al., 2007, 2008; BLUNT et al. 2009). Most likely, these results indicate a greater sensitivity of Scandinavian than of US strains of *M. nivale* and *T. incarnata* to propiconazole and fludioxonil due to less use of fungicides on Scandinavian golf courses.

The substitution of Banner MAXX with Headway for the first application in October resulted in the same level of control of *T. incarnata* at Arendal GC and of *M. nivale* at Österåker GC. In the 2011-12 trial at Bioforsk Landvik, the effect of two applications of Headway on microdochium patch was better than expected from JUNG's report (2007) on poor control of *M. nivale* with azoxystrobin, and also from Norwegian *in vitro* trials showing less efficacy of azoxystrobin than of propiconazole on Norwegian strains of the same pathogen (HOFGAARD et al., 2009). We conclude that the first application of systemic fungicide the turf is still growing in October can be conducted with either Banner MAXX or Headway. According to Syngenta's labels, propiconazole and azoxystrobin require temperatures higher than 6 and 10°C for maximal efficacy, respectively.

A main objective of this research was to evaluate the need for Medallion as a supplement to earlier application(s) of systemic fungicide. In this respect, the results from Österåker in 2012-13 were not consistent, but the trials from Bioforsk Landvik in 2011-12 and Arendal GC in 2012-13 showed enhanced control and/or better overall impression in spring with increasing number of applications of Medallion in the fall. For golf courses aiming for complete control of *M. nivale* and *T. incarnata* with a the lowest possible number of fungicide applications per year and with the lowest risk for fungicide resistance, one or two applications of Medallion after the initial application of a systemic fungicide in October is therefore a better alternative than multiple applications of Banner MAXX in fall and spring. At least in continental and northern parts of Scandinavia, the spring period is usually short and intense with limited risk for severe outbreaks of microdochium patch.

How long should turfgrass managers aiming for complete control of *M. nivale* and *T. incarnata* wait after the initial application of a systemic fungicide before making the first application of Medallion? The answer to this question depends on the weather conditions in the late fall, but the results from Landvik in 2011/12 and Arendal GC in 2012/13 suggest that six weeks was too long to offer complete protection of the turf. Rather than waiting until a few days before snow fall, greenkeepers should therefore monitor the turf closely and if necessary apply Medallion at 3-4 four week intervals after the initial application of the systemic fungicide. If the systemic fungicide is sprayed according to recommendations when the turf is still growing in October, this usually means one or two applications of the contact fungicide after mowing has been discontinued for the season.

Acknowledgement

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Fairy ring effects on soil and turfgrass growth and non-chemical control measures

Bocksch, M.

Introduction

Fungi as heterotrophs must obtain carbon by decomposing dead or living organic matter. Because of this, both the "higher" and "lower" fungi are playing a vital role in the cycle of nature. To the first group belong the Basidiomycota – which are my subject – the second group is the Ascomycota. Because of their hyphae with clamp connections, Basidiomycetes fungi are reliably identified under a microscope at > 100x to 400x. There are about 30,000 species worldwide. They are colonizing and decomposing organic matter within the soil, or among leaf litter on the soil surface.

Fairy rings

Some species of Basidiomycota show a very characteristic pattern of mycelium growth. It is growing in concentric circles or arcs known as "fairy ring" or "Hexenringe". This habit of growing is due to the even colonization of dead organic matter and possibly lignin available in a unique concentration within the soil and on the soil surface.

Over 60 native fairy ring-type basidiomycete species are able to show such a habit of growing. We will find them in forests as well as on pastures or turfs. The species *Clitocybe, Agaricus, Amanita, Tricholoma, Lepiota, Paxillus* and many other can be found in turfgrass stands, and one of the most common is *Marasmius oreades* which can cause massive problems in turf (Figure 1).

Every circle or arc starts from a single spore or piece of mycelium. The mycelium can only grow where organic matter, water and adequate temperature are available. From the central starting point, it is only able to grow towards the outside in a radial fashion, as it progressively colonizes and depletes the organic matter. After colonization the mycelium grows and matures, and under certain conditions (enough water and sufficient temperature) mushrooms may emerge on the surface. Once all of the organic matter is decomposed inside, the mycelium will die. However, the fungal mycelium on the outside of the ring will continue to grow 10 – 25 cm per year. Fairy ring fungi can become old. The wider the circle the older they are and some rings in lawns are 5 – 10 m in diameter.

Fig. 1: Picture of a severe fairy ring damage on a German sports field.

Fairy ring types and effects on the grasses

Living parts of plants are not the target of these fungi. However, it is possible that the mycelium is taking up substances released by the plants that are necessary or useful for the fungus. Also, turfgrass can benefit since the fungus does not use all substances from the decomposed organic matter. These nutrients are getting released and some of them are beneficial to the growing grass in proximity to the fairy ring (e.g. nitrogen containing compounds). As a result, the grass growth will be stimulated and shows an atypical dark green colour compared to the rest of the lawn.

The outside of the fairy ring has a narrow strip of healthy turfgrass growth with darker leaves, which is the result of the decomposition of dead organic matter and the release of nutrients (e.g., nitrogen) in this area. Depending on the width of the ring, the following strip will be more or less wide and shows "normal" grass growth. If the conditions are ideal, this is the area where sometimes mushrooms or puffballs will appear on the surface. Behind this area of the circle there are no mushrooms to be seen, but the grass is once again healthy with darker green leaves. This is due to the death and decomposition of the mycelium that releases nutrients useful for the plants.

Once the fungal mycelium has colonized the soil, it will grow intensively. Sand and soil particles will be coated by the mycelium. These particles become hydrophobic with the result that the entire affected area becomes hydrophobic. Water is no longer able to penetrate the soil and the grass roots are losing access to water. The turfgrass starts to show symptoms of drought stress and later the plants will die. In Central Europe this is especially typical for the fungus *Marasmius oreades*. The release of toxic compounds in the soil rootzone can also lead to unhealthy turfgrass growth. Tests performed by FIDANZA (2009) showed up to 70 times higher NH_4^+ concentrations from fairy ring fungi in the rootzone, compared to the rest of the lawn. This excess can lead to the death of the turfgrass. Drought always intensifies the effect. Within the necrotic zone, elevated levels of K, S, and electrical conductivity are also measurable, but the pH shows no difference.

Because of these changes in the growth of the turfgrass, we differentiate between three types of visual fairy ring symptoms in lawns and meadows:

Type I – shows necrotic symptoms and severe damage of the lawn within the circle (Figure 2);

Type II – shows a darker, stronger grass growth; mushrooms are rarely

Fig. 2: Picture of a Type I fairy ring of *Marasmius oreades* (Fairy Ring Mushroom) on a fairway.

Fig. 3: Picture of a Type II fairy ring of *Calocybe gambosa* (St. Georgs Mushroom) in spring.

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Fig. 4: Picture of a Type III fairy ring, here Amanita verna (Fool´s Mushroom).

present and there is no turf loss (Figure 3);

Type III – shows only mushrooms that form a circle; the rest of the year the circle is not visible (Figure 4).

Every kind of stress to the turfgrass leads to a stronger emergence of these visible fairy ring symptoms particularly of Type I and II. Stress can occur through low mowing, low fertilization with shortage of nutrients, heavy use, low temperatures or even the changes occurring with climate change in the last years (e.g., more frequent intense summer-heat and severe drought stress).

Plant protection and cultural practices

It is possible to successfully treat fairy ring-causing fungi with existing fungicides, mainly developed for the treatment of lower fungi pathogenic to turfgrass, however, in Germany their use against fairy ring fungi is not allowed.

Some combinations of different maintenance practices cause a strong reduction of the fungus and the resulting symptoms. Therefore green keepers and groundsmen must manage water and nutrients and use wetting agents, which are able to combat the water repellent mycelium effect.

Higher doses of nutrients, especially nitrogen and iron, "mask" Type I and II fairy ring symptoms by inducing stronger turfgrass growth and darker green leaf colour, but raise the costs for nutrients and mowing. Water applications on Type I fairy rings can only prevent the grasses from dying, if it is possible to buffer the water repellent effect.

Many trials performed by FIDANZA on golf greens and sports grounds, and also field trials in Germany, performed by Compo, show the importance of wetting agents in managing turfgrass affected by fairy ring.

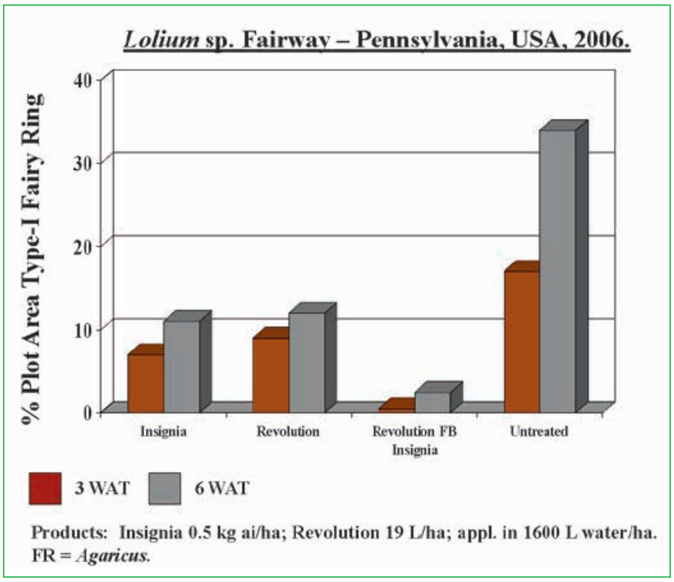

Fig. 5: The effect of a wetting agent is nearly as good as fungicide use. Three weeks after treatment as well as six weeks after treatment. Only the combination of both shows a significantly better result. FIDANZA M. from his lecture "Fairy Ring and Localized Dry Spot Issues for Golf Courses and Sports Fields" (2013).

Fig. 6: Picture showing two fairy rings severely affecting each other by their own chemical 'weapons' and causing a reduction of the ring growth.

For example, two spot treatment trials with water and wetting agent (19 L ha^{-1} Revolution in 1600 L water ha^{-1}) on aerated turfgrass show very positive effects for reducing fairy ring symptoms. This wetting agent program significantly reduced the area of Type I fairy ring of *Agaricus* after 2 to 3 weeks and helped to correct the water repellence effect by 4 to 6 weeks. The effect of aeration and the wetting agent Revolution is nearly as good as using the fungicides Heritage or Insignia. Only the combination of wetting agent and fungicide shows a still better result (Figure 5). Practice tests on a sports field in Halberstadt, Germany, with the soil surfactant Kick LDS (two treatments with 20 L ha^{-1} Kick LDS in 600 L water ha^{-1}) in combination with a 20 cm deep aeration and a sufficient post-application irrigation, lead to a complete reduction of the *Marasmius oreades* fairy rings in the same year.

Vision

Some fairy rings are only arcs that are always open on the downhill side. It is hypothesized that metabolic products containing prussic acid are one reason for the death of the grass in the ring and for the killing of the fungus downhill. Fungi metabolic products are often effective to control and limit the growth of other fungal competitors and may be responsible for the visible inhibition of both rings when they grow into each other (Figure 6). Metabolites transported with water downhill become effective in controlling other fungal colonies of the same species and even of the own same fungiorganism Detection and purification of these active metabolic compounds are hopefully opening new possibilities for the control of fairy ring.

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Turf quality concept for stadium pitches in the German Bundesliga

Mueller-Beck, K. and H. Nonn

Introduction

The turfgrass pitches in the stadiums of the First and Second "Bundesliga" have to offer an optimal pitch quality to guarantee a fair match service according to the rules. Besides the sportive and protective functions of the turfgrass also the visual aspects for TV broadcasting are considered.

To ensure the high quality of the turfgrass surface, the Deutsche Fußball Liga (DFL), who is responsible for the organisation of the "German Soccer League" (Bundesliga), has set up an expert team in 2011, which developed within one year a three stage quality concept.

Stage 1: Evaluation and monitoring system (since season 2012/2013);

Stage 2: Further education program (in implementation phase);

Stage 3: Annual Award "Pitch of the Year" (in preparation).

This article presents and explains the content and results of the quality concept's Stage 1 "evaluation and monitoring system".

Stage 1: Evaluation and monitoring system

This assessment system, which was introduced in the season 2012/2013, is based on two parts and is obligatory for all clubs in the First and Second Bundesliga.

1. General evaluation of the pitch quality by both team captains (guest and home) and the referee on each Matchday.
2. Measurement of the following quality parameters: sward density, water infiltration rate, shear strength and evenness (figures 1 to 4) at eight given times during the playing season on predetermined measuring points (figure 5).

Fig. 1: Sward density measured by ground cover rate.

Fig. 2: Water infiltration rate measured by double-ring infiltrometer.

Fig. 3: Shear strength measured by vane apparatus.

Fig. 4: Evenness measured by level indicator (optional).

Fig. 5: Position of the measuring points on the pitch (SD = sward density, W = water infiltration rate, S = shear strength).

Results

1. General evaluation

The subjective estimation of the pitch quality by the two team captains and the referee directly after the match, based on the individual playing experience, uses a five-scale ranking from 1 = poor to 5 = excellent with a comment function. The rating is transmitted online to the DFL and is stored in and interpreted by using a database. The additional comments to the ratings allow to draw conclusions from the reasons for positive or negative assessments. These comments are helpful for the groundsmen to initiate specific maintenance procedures.

During the season 2012/2013 the pitch quality in the Bundesliga was rated an average of 3.9 (min. 3.4 end of February and max. 4.5 mid of May), which is indicating a very good pitch quality (figure 6). The quality rating for the pitches in the second league reached the average of 3.6 (min. 2.8 beginning of February and max. 4.4 mid of September) which means a good quality aspect too.

The curves in figure 6 are showing a decline for the turf quality from the beginning of the season to late winter. With the start of the second half in the Bundesliga (end of January) the quality is increasing. The reasons for this are the applications of maintenance and renovating procedures as overseeding or renewing of the sods. Additionally, in spring the plants growing season starts and regeneration growth begins.

2. Measuring and Monitoring

Measurements of the quality parameters are done by the groundsmen. The methods are based on European or German standards (Table 1). This standardized basis allows for the comparison of the data among each other, and for the pooling with later data to find and compare trends.

The above-mentioned standards were used as target value. When there are no adequate minimum requirements defined by the standards, the values identified during the measuring periods can be used as threshold for the future.

During the season 2012/2013 the measurement of the specific quality parameters was conducted everywhere at the same time (within 1 week), and repeated 8 times during the playing

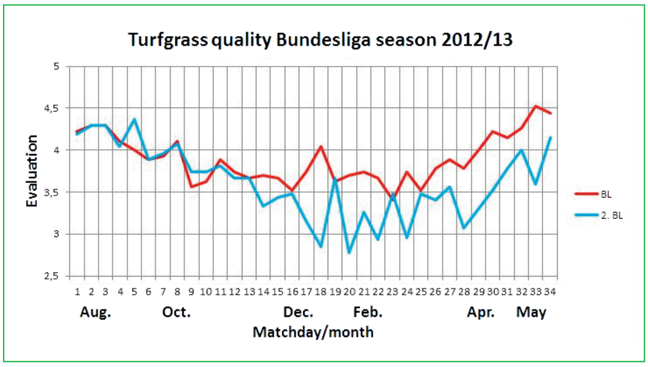

Fig. 6: Ranking of turfgrass quality evaluation during playing season 2012/2013 (average of each Match day in "First Bundesliga" (BL) and "Second Bundesliga" (2.BL)).

Quality criteria	EU or German standard
Sward density	DIN EN 12231:2003-07, method B
Water infiltration rate	DIN EN 12616:2003-07, method B
Shear resistance	DIN 18035-4:2012-01
Evenness	DIN 18035-4:2012-01

Tab. 1: Quality criteria and standards for evaluation.

	Sward Density (%)								
	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9
cw 32	97	97	97	97	97	97	97	97	97
cw 40/41	97	96	97	97	96	97	97	96	97

	Water infiltration Rate (mm/h)			
	WS1 mean	WS2 mean	WS3 mean	WS4 mean
cw 32	45	72	79	42
cw 40/41	55	68	66	49

	Shear Strength (kPa)			
	WS1 mean	WS2 mean	WS3 mean	WS4 mean
cw 32	48	50	53	52
cw 40/41	57	56	47	63

cw = calender week

Tab. 2: Example of results of the quality tests at different times (cw 32 and cw 40/41) in one soccer field, the BayArena Leverkusen ("First Bundesliga").

season. As an example, the test results of the stadium in Leverkusen for two measuring periods are shown (table 2).

Now, as a result of the first measurement period, the data, averaged over the season and over all stadiums, serve as base mean value for the quality. Measuring the evenness was optional and therefore it is not considered in the results. On average, over the complete season of the Bundesliga, the following results were ascertained:

- 90 % sward density;
- 30 mm/h water infiltration rate;
- 60 kPa shear strength.

These data serve as threshold value for future good quality turf on the stadium pitches.

Conclusion

The collection of objective, measurable parameters and their correlation with subjective ratings of turf quality, establish a clever strategy for the management of the stadium pitches quality. Furthermore the regular control and documentation of the specific criteria provides the groundsmen in charge with useful decision guidance for the safeguarding of the turf quality.

Measuring and evaluation attest a high quality standard in the stadiums of the German Bundesliga and 2. Bundesliga. Potentially the present measurements could be completed with the introduction of other quality parameters, like resiliency, strength reduction, ball roll distance to mention but a few.

The positive acceptance and the implementation of stage 1 of the DFL quality concept by the groundsmen, and the rising attendance for education and advanced training (stage 2) acknowledge the significance of both quality levels: quantitative data and qualitative information.

Based on the positive experience with stage 1 implementation of the turf quality concept, now the basis for stage 2 "education and advanced training" has been laid. This then leads to the annual Award "Pitch of the Year" (stage 3). The DFL-expert team is confident, that the high quality standard of the German Bundesliga stadiums will permanently maintained and even enhanced.

Annex: „Turf quality concept for stadium pitches in the German Soccer League"

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Hybrid turf systems for more wear tolerance on soccer pitches

Nonn, H.

Introduction

Natural turf on soccer pitches has to withstand a lot of stress. Compression and shear forces compact the root zone and damage the turfgrasses especially in the mainly used areas. This leads to lower sward density and uneven playing surface with the effect that appearance and performance decrease. These disadvantages can be minimized by stabilizing the root zone mix and/or sward. In addition, stabilized soccer pitches, called "hybrid turf", could be an alternative to the expensive and often problematic fully artificial turf over rubber infill.

About 50 years ago products like Enkamat, Austria-Grasvlies and turfgrass protection mat Point 15R were introduced in the market. None of these products was successful.

During the last two decades different systems entered the turfgrass market. These systems can be divided in two groups: systems that stabilize the root zone mix, and systems that combine a stabilization of the root zone with the sward. Practice has shown that, regarding sport performances, there are differences between these systems. To understand these differences a closer look to the construction and the components of the systems is necessary.

Systems to stabilize the root zone mix = hybrid root zone mix

In these systems plastic fibres or plastic grids are added to the root zone mix. The root zone is mainly based on sand and fibres/grids are mixed in outside of the pitch. After installing the root zone mix the turf is sown with a mixture of *Lolium perenne* and *Poa pratensis*, or sometimes up to 100 % of *Lolium perenne*. Brand names* for hybrid root zone mixes are Netlon Advanced Turf, Fibreturf, Fibrelastic or Terrasoil Advance.

* registered brand names in this report are not marked with ®

Netlon Advanced Turf contains plastic grids in the root zone mix. It is mainly used for event areas, parking areas and approaches.

Fibreturf is a mixture of a special sand based, root zone mix and non-elastic polypropylene fibres. Fibrelastic is based on Fibreturf but with additional elastic polypropylene fibres. Both root zone mixes are mainly used for soccer pitches.

Terrasoil Advance is based on the root zone mix Terrasoil containing approx. 18 cm long polyethylene fibres which are randomly distributed in the soil.

Fig. 1: Intensively used area on Terrasoil Advance root zone mix with nearly no grasses but even surface.

Fig. 2: New constructed soccer pitch with Fibrelastic root zone mix stabilizing root system and surface.

Systems to stabilize the root zone mix and the sward = hybrid turf

GrassMaster was introduced 20 years ago as the first system to stabilize sward and root zone. In a special sandy root zone mix tufts of PE-fibres are grooved 16 cm deep in a distance of 2 cm. Fibres stay 2 cm above the surface to stabilize grasses.

XtraGrass, developed in the Netherlands, uses an artificial turfgrass mat partially biodegradable. The mat with its 70 mm long tufted PE-fibres is installed on the root zone mix, filled with approx. 5 cm root zone material and seeded.

PowerGrass is the newest development in hybrid systems. A woven, not degradable, permeable for roots, water and air, artificial turfgrass mat with 45 mm long PE-fibres is placed on the root zone. 25 mm of root zone material is added and seeded. The fibres stabilize the roots and protect the plant crown and the grass leaves.

All hybrid turf systems are mainly used for soccer or similar turf sport events.

Fig. 3: Hybrid turf system PowerGrass: stabilization mat in the root zone, filled with 2.5 cm root zone mix.

Fig. 4: Soccer training area: Sward injuries on PowerGrass (top left) compared to not stabilized turf (down right).

Construction costs

All these systems, on top of the costs for a solid and well draining soil foundation, require the following additional financial efforts (averages for a soccer field, pre-tax):

Netlon Advanced Turf:	+ 400,000 €
Fibreturf:	+ 200,000 €
Fibrelastic:	+ 300,000 €
Terrasoil Advance:	+ 60,000 €
Grassmaster:	+ 300,000 €
XtraGrass:	+ 300,000 €
PowerGrass:	+ 150,000 €

Maintenance of hybrid systems

All maintenance actions have to keep and to optimize wear tolerance as well as the stabilizing system for a long time. This means that all actions, except topdressing, necessary to maintain an excellent soccer turf have to be applied intensively.

Topdressing is prohibited or strictly limited due to the fact that the fibres will be buried and thus taken out of function. Effects of sanding have to be replaced by grooming, scarifying, sweeping and matting. Coring with solid tines is possible in all systems, hollow tines shall not be used because they cannot penetrate into the root zone or they would damage the stabilizing materials. Regeneration of the sward has to be done by recurrent overseedings because inset with sods or plugs is not possible. Thicker sods of XtraGrass and PowerGrass are available and may be used for new installation or partial repair such as goal or penalty area.

Conclusion

Due to their stabilization, hybrid root zone mixes and hybrid turfs provide the chance to increase sports turf usage and quality but they cannot reach the yearly use intensity of an artificial turf because grasses pose a limit to the wear tolerance.

In practice, the hybrid turf systems can stand increases of up to 2 hours per day of usage compared to not stabilized turf, with good turf density and surface evenness. This increase of usage is sufficient for most of the football clubs and therefore these systems are a real alternative to artificial turf.

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Characterisation of organic matter dynamics in sports turf

Evers, M. and A. Wolleswinkel

Background

A sports turf rootzone undergoes dynamic changes as plants and root systems grow, mature, and die. The debris of organic matter created in this cycle is deposited in the upper part of the rootzone. This process of organic matter accumulation, referred to as organic matter dynamics, has a major impact on the soil physical properties of the rootzone. Appropriately managing this cycle will lay the foundation for healthy turfgrass, and failure to do so can lead to many secondary problems (Hartwiger, 2004). Research done by CARROW showed that reduced oxygen levels, caused by the accumulation of organic matter in the surface zone, is the primary cause of many secondary problems experienced in sand-based root zones (CARROW, 1998).

Introduction

Many researches have been done on the organic matter build up in sports turf soil. Also much knowledge is available on how to control excessive amounts of organic matter in a top layer. However, much less is known about the quality of the organic matter. This quality is summarized in a CN-ratio. The total organic matter formed by the turf in combination with the CN-ratio can give information about the risk of thatch build up. It is expected that different turf grass species will differ in CN-ratio of the shoots and roots that could finally influence the CN-ratio of the soil organic matter. With this information the choice for specific turf grass varieties and/or changes to the maintenance programs can be improved.

Materials and Methods

Growth medium: The trial field was executed over sub-grade of coarse sand (383 µm) with 1.3% (LOI) organic matter covered with 15 cm topsoil (0-20 cm) of medium coarse sand (336 µm) with 5.8% (LOI) organic matter, CN-ratio of 18 and pH-KCl = 6.

Turf grass species: *Lolium prenne* (Lp), *Poa pratensis* (Pp), *Festuca arundinacea* (Fa), *Festuca rubra commutata* (Frc), *Poa trivialis* (Pt) and *Descampsia caespitosa* (Dc).

Maintenance: ordinary for sports turf pitches with a mean mowing height of 35 mm. The annual NPK application rate was roughly 120 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}. Irrigation was done in dry periods.

Trial setup: Randomized block design with 3 repetitions. Unifactorial trial per grass specie. Plot size: 1 x 2 m.

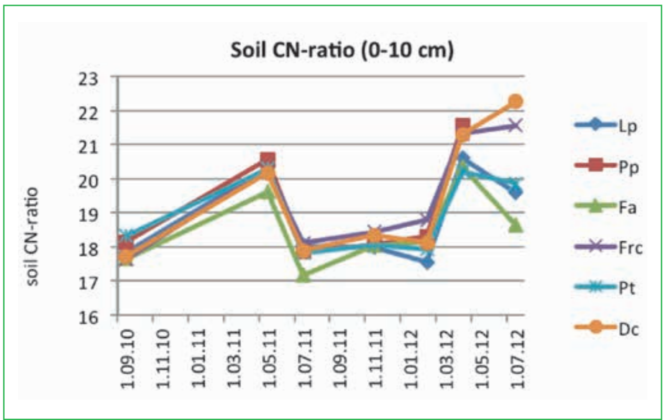
During the trial period 3 times a year (Spring, Summer and Autumn) 20 soil cores (0-10 cm depth) per plot were taken for C_{total} and N_{total} analysis in the laboratory. At the same time from every single plot the clippings were collected for fresh weight analysis and C_{total}, N_{total} and dry matter analysis in the laboratory. Dry matter analysis was done by overnight drying at 70°C followed by milling at 1 mm and drying at 103°C (gravimetrical method). For the N_{total} analysis the elementary Dumas method is used, C_{total} is measured via infrared spectophotometry.

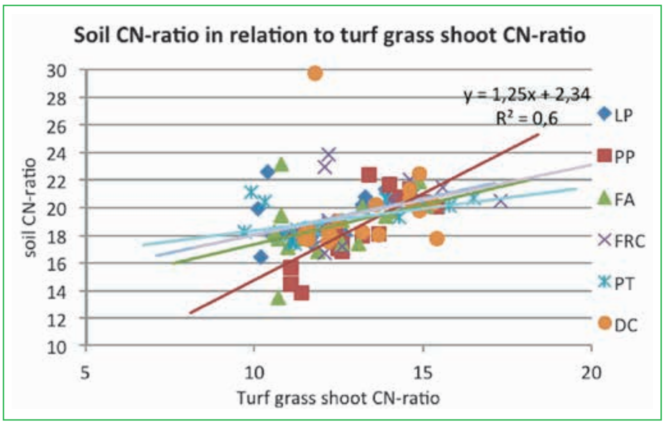
Turf grass shoot organic matter

After full establishment Frc and Dc gave the highest amount of C_{total} with the lowest N_{total}, followed by Pt and Pp. Lp provided opposite results (low C_{total} with high N_{total} content). As a result the CN-ratio for Frc, Dc and Pp tends to be higher than the CN-ratio of Fa, Pt and Lp. In general there is a strong seasonal influence on the CN-ratio.

Turf grass rootzone organic matter

CN-ratios of the soil show the tendency to increase with Frc and Dc and a more steady state with Lp and Fa. Pp and Pt are more intermediates. It results in more thatch build up with Frc, Dc and Pt. Lp gives the lowest thatch build up. As thatch build up by the turf grass only appears in the upper few cm of the soil and the C_{total} and N_{total} analysis is done for the 0-10 cm soil layer (which is a standard depth for sports turf) the influence of the soil sampling depth and the relatively high initial CN-ratio of the soil weakened the overall results. Nevertheless some trends at the end of the trial are shown.





Practical Paper

Conclusions

There seems to be the tendency that turf grasses, like Frc, Dc and, to a lesser extent, Pt and Pp, with a high fresh and dry matter production, with relatively high C_{total} content and relatively low N_{total} content in the shoots, will give a higher risk for thatch build up with increasing CN-ratio of the soil than other turf grasses.

There is a weak correlation between CN-ratio of the turf grass shoot and the CN-ratio of the topsoil. Pp shows the strongest correlation. It is expected that this correlation will be much stronger in a more sandy soil with lower organic matter content and lower initial CN-ratio.

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Report on the conditions of the soccer pitches in Germany

Albracht, R. and H. Nonn

Introduction

About 25,000 lawn soccer pitches in the Federal Republic of Germany have a size of more than 5,000 m² (SPORTSTAETTENSTATISTIK, 2002). Quality parameters as type of soil construction and level of maintenance decide about their usage and resilience. The objective and repeatable evaluation of the performance gives a proper base to determine the necessary measures for conservation or amelioration of the pitch.

Material and Methods

Since 2005 Eurogreen has used a standardised questionnaire to evaluate soccer pitches. Until the end of 2013 2,535 turf soccer pitches were evaluated on that base and the data were interpreted. The results in this report only show the data of the first pitch analysis. Data of the following years, which represent the development of the pitch performance, are not considered. The most important quality parameters are:

- type of soil construction;
- characteristics of the rootzone (drainage, compaction, evenness);
- sward density and botanical composition;
- thatch, rooting, shear strength.

The evaluation of the data was done by experienced turfgrass consultants using visual methods, estimations and easy to execute measurements.

Results

Soil construction (Figure 1): 50 % of the inspected pitches have a soil constructed according to DIN 18035-4 (DIN, 2012). These are mainly pitches built after 1974, after the launch of this standard specification. The other 50 % are pitches neither constructed according to the norm nor showing any noticeable soil construction.

Water infiltration (Figure 2): 84 % of the pitches offer a good to medium

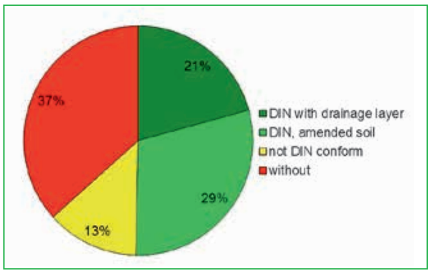

Fig. 1: Soil construction

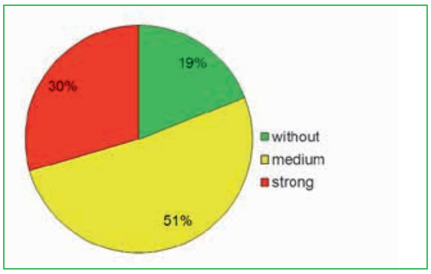

Fig. 3: Compaction rootzone

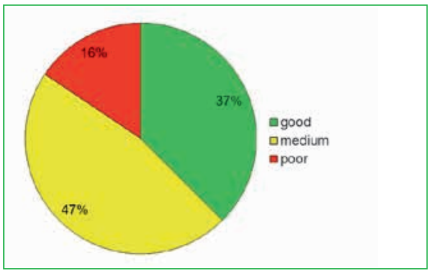

Fig. 2: Water infiltration

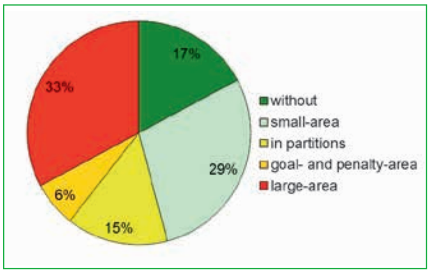

Fig. 4: Unevenness

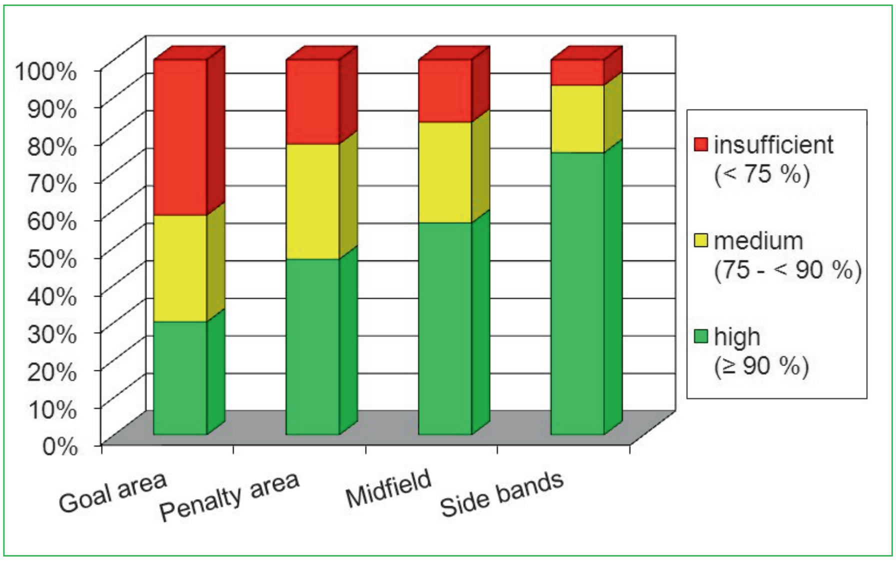

Fig. 5: Sward density

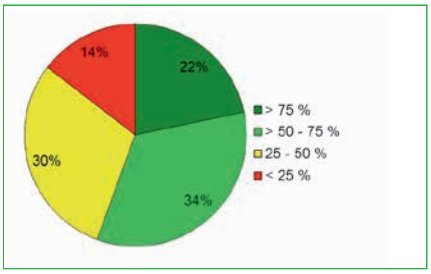

Fig. 6: Ground cover sports turfgrasses

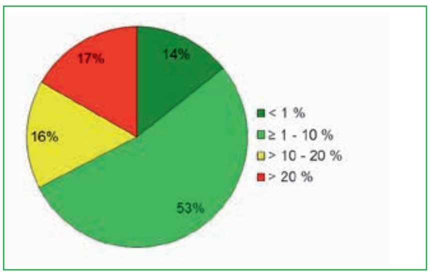

Fig. 7: Ground cover broadleaf weeds and legume

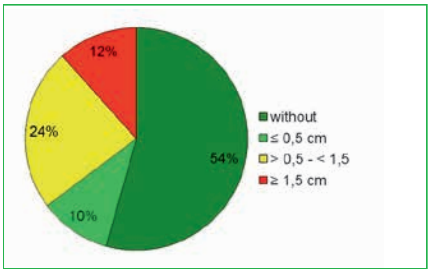

Fig. 8: Thatch accumulation

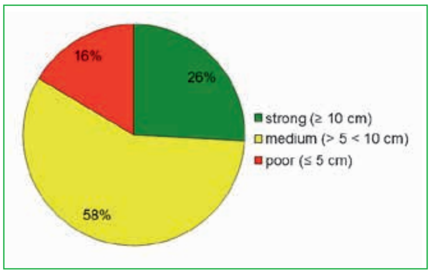

Fig. 9: Rooting

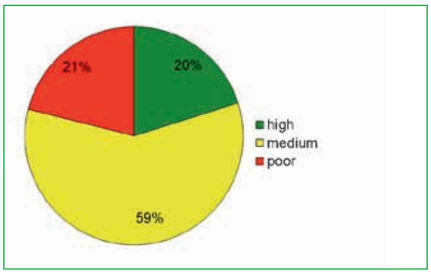

Fig. 10: Shear strength

water infiltration. Only 16 % are rated as poor. This suggests that the pitches have sandy root zones and/or efficient drainage systems.

Soil Compaction (Figure 3): 30 % of the root zone mixes are highly compacted and another 51 % are medium compacted. This high proportion is an indication of insufficient soil loosening or angular construction materials, e.g. Lava.

Ground Evenness (Figure 4): More than half of the pitches show disrupting unevenness. This concerns especially goal areas and penalty areas due to their high usage.

Sward density (Figure 5): A dense sward offers ideal properties for football game and players. High densities (> 90 %) are primarily found along the side bands, in the goal area high sward density is present in only 24 % of the pitches.

Botanical composition (Figures 6 and 7): sports pitches should be covered by high density turf of *Lolium perenne* and *Poa pratensis*. Only 22 % have more than 75 % of these species, in fact 44 % of the pitches show less than 50 % of these two species. One third of the pitches shows more than 10 % broadleaf weeds and legume coverage.

Thatch (Figure 8): Thatch accumulation up to 0.5 cm is acceptable. Most of the pitches (64 %) comply with this requirement. Only 12 % have thatch layers more than 1.5 cm thick.

Rooting (Figure 9): Poor rooting (< 5 cm) is measured at only 16 % of the pitches. Most of the fields (58 %) vary between 5 and 10 cm, the middle and lower zone of the vegetation layer.

Shear strength (Figure 10): The small number (20 %) of pitches with high shear strength correlates to the number of pitches showing more than 75 % of *Lolium perenne* und *Poa pratensis* (Figure 6). This indicates the importance of the right botanical composition regarding the quality parameter of shear strength.

Conclusion

Generally all reviewed turf pitches offer a good to medium potentials for soccer. The good water infiltration matches the needs of the climate in Middle Europe. Compaction of the rootzone, unevenness and not suitable botanical compositions are frequent. Mechanical soil treatment, measures to increase evenness and amendment of botanical composition have to be intensified. Quality parameters shown in this report are useful tools for operators and groundsmen to define the required activities for preservation or amelioration of their pitches.

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Multifunctional golf facilities as a driving force in implementing the European Landscape Convention: a case study in Sweden

Strandberg, M., K. Schmidt, O. Skarin and L.-G. Bråvander

Introduction and background

The European Landscape Convention (ELC) is the first European agreement to specifically present the landscape as a resource for multiple uses and an important precondition for sustainable development. The convention come into force 2004 and it is the first agreement to be exclusively devoted to all aspects of European landscapes. The ELC was ratified by Sweden in May 2011. The ELC provides us with a framework for developing the landscape. It states that the landscape is a shared asset and a shared responsibility. The aim of the ELC is to promote people's quality of life and well-being by promoting European landscape protection, development, management and planning and to organise European co-operation related to this. The ELC has a holistic approach to culture, nature, outdoor activities, sports, and economic development of a defined area (ELC, 2013).

Europe´s landscape has faced more habitat loss and fragmentation than any other continent. This is a major problem for biodiversity, ecosystem services and outdoor recreation. Extensively managed turfgrass areas can promote critical ecosystem services and help to restore and enhance biodiversity in ecologically simplified landscapes such as agricultural and urban land (EU 2011, STRANDBERG 2012a). The development of multifunctional golf courses as the core in a geographically larger landscape can comprise establishment or conversion of facilities and functions, with the aim of contributing to society's many different values, whether cultural, ecological, aesthetic, social or economic (STRANDBERG, 2011; 2012b).

The area around Garnsviken and Sigtuna Golf Club, 2 km northeast of Sigtuna, Sweden, is a naturally defined area where conservation values as well as historical values and modern outdoor activities are clearly represented. The area is unique and contains a number of different types of landscapes that have conservational value, both from the result of human activity and from natural origin. Sigtuna with its medieval centre, is Sweden's first and oldest city dating back to 970 C.E.

The aims of the project are to:

- use the local golf Club as a driving force to improve the availability and sustainable development of the area containing cultural, nature and recreational values as well as economically viable activities in the defined area at Garnsviken;
- implement an open democratic pro-active "visionary planning process";
- identify, promote and expand business advantages of multifunctional activities for the golf facility as well as for the area stakeholders; and
- act as an "umbrella" project for all initiatives in the defined area and a coordinating platform for activities aiming to develop the area.

Results

The first phase of the project shows that a multifunctional golf facility can be a practical hub and a good example of cooperation on landscape issues and an instrument in implementing the ELC. The "visionary planning process" used within the project is a key tool for achieving shared responsibilities and good, efficient cooperation between more than 50 stakeholders representing authorities, institutions, developers, associations and private individuals, where all parties stand to gain. The co-operation has been adapted to the requirements and the specific challenges facing golf and other interests in the region. It has also been interdisciplinary, in other words encompassed a range of interests such as local authorities, national authorities, sports and recreation groups, landowners, residents, industry and others.

A golf course is an artificial environment where biotopes, such as pools, ponds, extensively managed turfgrass areas et cetera, which have decreased drastically in the agricultural and periurban landscape, are restored and provide threatened species with new habitats. Inventories made at Sigtuna Golf Club of plants, insects, birds, amphibians and bats show that the area contains a vast biological diversity (BRÅVANDER & DRAKENBERG, 2008). Many golf courses have revealed their cultural monuments through setting up information boards and installing footpaths leading to these objects. Through collaboration with the National Property Board of Sweden, museums and the local history society, the golf club and stakeholders in the area have obtained private, local and governmental guidance and practical and financial support for renovating or preserving ancient monuments and the history of the area, for example, a number of cultural buildings and locations at Viby By and Wenngarn Castle.

The accessibility of golf courses varies. This one has a policy to actively promote non-golfers to visit the course, to experience the nature and culture, visit the restaurant and try out golf at the practice area. Within the project, three seminars, based on visionary based planning, have been arranged. In all, about 100 persons have attended the seminars. The first seminar gave a short introduction to sustainable landscape development and multifunctional golf facilities. At the following workshop 75 persons defined 100 project ideas that would be possible to conduct in the area. During the second seminar the auditorium took on the task to prioritize among the 100 suggested project ideas and came up with one idea supported by everyone: enhancing the infrastructure in the area in order to make it more accessible. The first step is to build a bridge, 3700 m long, for walking and cycling, adjusted for disabled persons. The bridge will be built in the reed belt on the marsh between the golf course hole number 16 and 17 and the open water of the lake. It was decided that the first leg, 1450 m, will be opened May 9th 2015.

Further actions underway and intended

The project includes seven sub-projects within the defined geographic area. The aim is to develop the project into an important forum for communication and action, involving all sub-projects and stakeholders in the area. As a part of the project, the concept of using multifunctional golf facilities as a driving force and a hub for sustainable landscape development will be spread internationally to begin with in Europe, Canada and China. The ambition is to nominate the project for the Landscape Award of the Council of Europe, the objective of which is to reward exemplary practical initiatives aimed at successful landscape quality objectives on the territories of the Parties to the Convention.

Acknowledgement

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Soil and vegetation characteristics of a golf course in a Southern Russian floodplain

Gorbov S.N. and O.S. Bezuglova

Introduction

The natural soil cover of the Don-Aksay floodplain territory is a compound polygenic soil system with various composition and complex soil cover (POLYNOV, 1956; BEZUGLOVA et al., 2012a). On the upland territories, formed by bedrock with light texture, there can be seen alluvial meadow stratified soils (Fluvisols according WRB) (WORLD REFERENCE BASE, 2006), on the lowland territories alluvial meadow-boggy soil and alluvial-boggy gley soil (Gleysols, according WRB). However, the basis of soil cover mostly consists of saline alluvial meadow soils of various deep and heavy texture (salinik Fluvisols according WRB).

Photo 1: Alluvial-meadow soil (Fluvisol).

Taking into consideration the given information, the decision to construct a golf course in this place was purely determined by historical attractiveness of the place and its proximity to the river Don. Ecological soil characteristics were largely not considered, and soil properties had little importance in the selection of a place for the construction of a golf course.

Materials and Methods

Research was conducted in the right bank floodplain of the river Don, on the territory of Starocherkasskaya village (Rostov region, the South of European part of Russia). Alongside with early soil investigations (1936, 1956, 1977) a fourth detailed examination was carried out in 2003, prior to golf course construction. More extensive soil examinations were carried out in 2005-2007 during golf course construction. To do this a full profile pit was made in the area of the future golf course, with obligatory selection of soil samples both horizontally and from the surface. To classify the soils, specialists defined its chemical and physical features with the help of standard methods generally used in Russian Federation. Total humus content was determined by using a wet combustion via a mixture of potassium dichromate and sulphuric acid at about 125°C. Soil salinity was determined using the saturation extract method following government standard #26424-85. Soil bulk density was determined by the following method. A metal cylinder of known volume was pressed into the soil and the mass of the sample was weighted. The sample was then oven-dried and weighed again. The bulk density is the ratio of dry mass to volume at the determined water content. Determinations were made in triplicate. The content of sand, clay and silt fractions was determined by the pipette method (VOROBYOVA, 2006).

An additional soil examination and analysis of the territory was conducted during 2008-2012, following golf course construction and soil disturbance for the construction of the course. This examination revealed spots with initially native soil types and artificial soil-like formation, forming the general basis for our hypothesis of newly formed soil types.

Results and Discussion

The process of golf course construction associated with the movement of soil horizons and parent material had two main objectives. First, the golf course architect desired a slightly wavy surface as the final concept of the course. Second, it was necessary to raise the golf course surface to a certain level higher than native surface to prevent flooding of the playing area. Construction resulted in the shift of the upper 20 centimeters of soil, and it was stored offsite. Next, for channel and pond de-

Soil type	Horizons	Depth cm	Total humus %	Salinity %	Sum of fraction, size <0.01 mm, %	Bulk density g/cm^3
alluvial meadow soil (Fluvisol)	~~d~~	0-10	2.08	0.05	55.04	1.05
	~~1~~	10-40	1.15	0.08	56.60	1.37
	—	40-60	1.04	0.06	45.36	1.39
	~~1~~	60-80	1.85	0.07	87.40	1.30
	~~2~~	85-30	1.06	0.24	73.76	n/d
	—	130-145	n/d	0.41	47.04	n/d
chernozemic meadow soil	~~p~~	0-24	3.60	0.049	74.12	1.28
	—	24-50	2.32	0.063	58.76	1.42
	—	50-60	3.56	0.078	65.44	1.56
	—	60-85	2.79	0.165	57.96	1.51
	—	85-100	0.68	0.480	50.00	n/d
alluvial gley meadow soil (Gleysols)	~~d~~	0-10	4.57	0.05	79.28	1.02
	~~1~~	10-24	2.53	0.07	57.44	1.25
	~~g~~	24-44	1.18	0.10	51.32	1.31
	~~1~~	44-56	1.42	0.12	65.20	1.31
	~~2~~	56-90	1.73	0.29	81.84	n/d
	—	90-125	3.22	0.50	84.36	n/d

* n/d – not determined

Tab. 1: Physical and chemical properties of natural soils.

velopment, soil layers and their parent material were extracted at 3-4 meter layers, stored, and later were used as the basis for the future play zones.

As a result of such laborious work, there was created a totally new slightly wavy surface among the flood-plain landscape by means of shaping. Almost all native soil types which were located above sea level were either made thinner or its top layers were removed (GORBOV, 2012). The original territory above sea level was 1.0 - 1.2 m. During a building of the golf course all Fairways and putting greens were raised up to 2.0 - 3.2 m. above sea level and tee zones were raised up to 2.0 - 9.0 m. above sea level. The soil cover of game holes consist of artificial soils, the lower part of which is composed of various granulometric composition of ground and the upper part is composed of horizon A of alluvial meadow stratified soils (Fluvisols). On this territory before golf course construction only 7 natural soil types could be identified, and currently the given territory consists of 15 newly framed (artificial) soils.

According to our research the top horizon of Fluvisols in construction territory had the medium humus content (2.1-4.6%).

Despite of this the normal development of a lawn was impossible because of the heavy texture of Fluvisols and the amelioration of the topsoil was necessary. (BEZUGLOVA et al.,2012b; GORBOV, 2012; BEARD, 2002). All fairways were amended with A horizon material consisting of alluvial and chernozemic soils from meadows. This was done to ensure a quality planting medium for lawn grasses.

Photo 2: Tee and Fairway of hole # 4.

The soils of the intermediate zone (roughs), on the contrary, were preserved in a natural condition, because only minimal top layer (no more than 20 centimeters) was removed. The unfavorable air-water ratio in the soils of the rough area along with the usage of a non-aggressive grass (*Festuca ovina*) allowed for the return of the natural flora of the floodplain which is replacing the manmade lawn of the roughs.

Photo 3: Plant association of Rough.

Over time the development of a particular plant type association occurred, with the natural vegetation representatives of the floodplain of the river Don, among which are more common species of the such kinds as *Artemisia, Veronica, Carex, Chenopodium, Cichórium, Elytrigia, Trifolium* etc. existing in the roughs.

Conclusions

1. Design visions of the golf course architect resulted in the development of a complex soil cover within this golf course site. On this territory, before the golf course construction, only 7 natural soil types could be identified. After the construction 15 newly framed (artificial) soils were identified.
2. The considerable transformations completely changed the ecological condition of the agricultural land. In addition modern automatic irrigation systems and local drainage provides for the cultivation of stable lawns on artificial soils.
3. The golf club, constructed in the floodplain of the river Don, is a complex of natural and anthropogenic soils, which are ecologically stable and continue to fulfill natural functions, despite their considerable man-made transformation.

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Effect of different P-sources on turf quality

Albracht, R. and M. Schlosser

Introduction

An appropriate and sufficient supply of phosphorous is necessary for the development of a dense and wear tolerant turf. The economically exploitable sources of phosphate are limited worldwide and additionally the contamination with heavy metals (e.g. Cadmium) reduces the quantities of available high quality phosphate. This research was meant to evaluate whether P-fertilisers from alternative sources (e.g. recycling processes) are suitable for use on turf.

Materials and Methods

The experimental work was carried out on a sport field built accordingly the DIN 18035-4 (DIN, 2013) specifications, with a drainage layer and sandy soil with pH of 6.2, 5.3 mg P_2O_5 100 g^{-1} – 24.7 mg K_2O 100 g^{-1} and 6.1 mg Mg 100 g^{-1} soil. Based on a yearly uptake of 5 g P_2O_5 m^{-2} the 3 years need was applied at once and raked before seeding with a 50/50 mix of *Lolium perenne* and *Poa pratensis* specific for sports turfs in accordance with the RSM 3.1 (FLL, 2011) specifications.

The trial was established in June 2012 and structured with 7 treatments replicated three times, and plots of 4.5 m². Here the treatments list: control (without P-fertiliser), single superphosphate, (18 % P_2O_5), meat-and-bone meal (16 % P_2O_5), redox bone ash (39 % P_2O_5), sewage-sludge ash, from mono-pincineration (16 % P_2O_5), phosphite (42 % P_2O_5), and magnesium-ammonium-phosphate (24 % P_2O_5). The treatments meat-and-bone meal and magnesium-ammonium-phosphate contain nitrogen therefore a compensation fertilisation was applied to the other treatments to achieve a 25 g N m^{-2}. The other macro nutrients were added by mineral NK(Mg)-fertilisers four times a year. Plots were irrigated when necessary, frequently mowed at a height of 35 mm and turf clippings were collected. Dry matter yield and P-content in the clippings were measured of every cut. Turf quality was evaluated visually every week (TQ 9 = best quality).

Results and Discussion

During the first complete growing season the control showed the lowest dry matter yield (Figure 1), the lowest P-content (Figure 2) and the lowest P-removal (Figure 3) both at every cut and on average during the whole season (Table 1). The P additions in any form had positive effects on these data. The highest values were observed at the meat-and-bone meal treatment. The redox bone ash and sewage-sludge ash from mono-incinera-

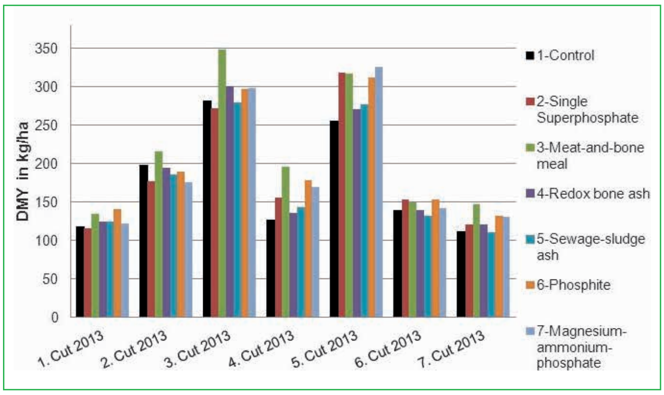


Fig. 1: Dry matter yield of sports turf according to the phosphate source.

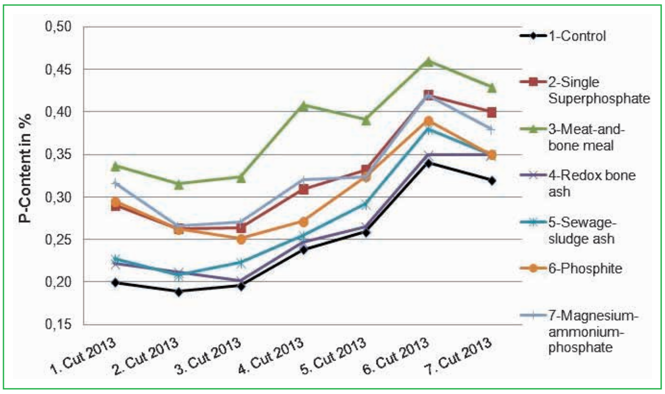
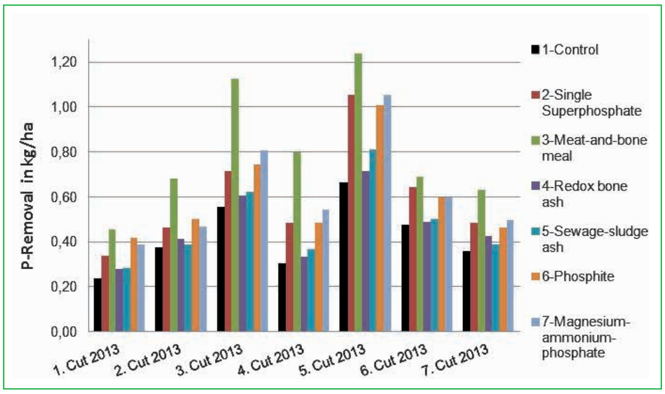


Fig. 2: P-Content of grass according to the phosphate source.



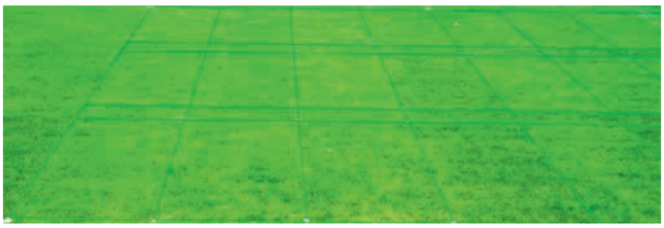


Fig. 4: Colour difference between some treatments during spring.

◀ Fig. 3: P-Removal according to the phosphate source.

Treatments	Ø DM Yield kg DM/ha	Ø P-Content % Pi. DM	Ø P-Removal (kg P/ha)	Total P-Removal (kg P/ha)
1-Control	175,7	0,2	0,4	3,0
2-Single Superphosphate	187,5	0,3	0,6	4,2
3-Meat-and-bone meal	215,4	0,4	0,8	5,6
4-Redox bone ash	183,7	0,3	0,5	3,3
5-Sewage-sludge ash	179,0	0,3	0,5	3,4
6-Phosphite	200,4	0,3	0,6	4,2
7-Magnesium-ammonium-phosphate	194,8	0,3	0,6	4,3

red: lowest, blue: highest

Tab. 1: Average DM yield, P-content, P-removal and total P-removal according to the phosphate source.

tion tended to result in second lowest levels, short above the control. The P-removal was similar or higher compared to single superphosphate (Table 1 and Figure 3) for meat-and-bone meal, magnesium-ammonium-phosphate and phosphite.

The visual rating in spring 2013 showed a blue-green colour of the grasses in the control plots, redox bone ash, and sewage-sludge ash from mono-incineration (Figure 4). This colouration suggests a stress situation caused by a lack of phosphate because an insufficient availability of phosphate at this time. Later in spring these differences disappeared. This could be caused by improved growing conditions and P-availability in these treatments.

The sandy soil with shortage of P_2O_5 (only 5.3 mg P_2O_5 100 g^{-1} soil) was ideal to show the influence of the different fertilisers. During the trial the P-content of the soil in the control plots decreased from 5.3 to 2.3 mg, P_2O_5 100 g^{-1} soil). For the next years it would be interesting to observe the change of the soil P-content and the occurrence of P-deficiencies in the grasses. The measures of the grass clippings P-contents in all treatments indicated no P-deficiencies, 0.2 % threshold according to BERGMANN and NEUBERT (1976).

In the following years the trial will show if a sufficient supply of phosphorus is possible even with P-fertilisers from recycling processes and if a stock fertilisation can be achieved.

The results showed that even the highest P-removal was bellow 20 kg P_2O_5 ha^{-1} per year. The common recommendation for P-fertilisation on sports turf is up to 100 kg P_2O_5 ha^{-1} and year (BISP, 1993) and thus clearly higher than the measured removal. Additionally the P-contents in the soil of older pitches (even with higher N-fertilisation and mowing frequency) are very often high and therefore revealing that the removal is lower than the recommended dosage. That leads to the conclusion that it is possible to fertilise with lower amounts of P than actually recommended without lowering turf quality.

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Impact of turfgrass fertilization on nutrient losses through runoff and leaching

Grégoire, G., C. Bouffard and Y. Desjardins

Introduction

Over the last few years, citizens of Québec have expressed increasing concern over the impact of turfgrass fertilization on water quality. This has led to the adoption of several municipal ordinances regulating the use of fertilizer on home lawns. However, those regulations are often not based on science, and their ability to reduce nutrient loading to water bodies has not been demonstrated. Furthermore, it has been previously shown that unfertilized turfgrass can result in higher nutrient losses compared to properly fertilized turf (EASTON and PETROVIC, 2004; HOCHMUTH et al., 2012; SOLDAT and PETROVIC, 2008). This is mostly the result of an increase in runoff volume caused by low tiller density in unfertilized turf (BIERMAN et al., 2010).

The objective of this project, initiated in 2011, was to quantify nutrient losses from turfgrass fertilized with two conventional fertilization programs (based on industry practices), and from one program based on a typical municipal fertilizer use regulation. Unfertilized treatments were also included as controls. The specific objectives of this project were to:

- compare the impact of different nutrient sources on runoff and leaching losses of nitrogen and phosphorus
- measure the impact of cultural practices (aeration, topdressing and overseeding) on nitrogen and phosphorus losses through runoff and leaching
- compare nutrient losses from standard industry fertilization regimes to that which happens when lawns are fertilized using practices required by municipalities.

Material and methods

For this project, 15 separated research plots were built during the summer of 2011. Plots were 5 m wide by 10 m long, and had a v-shaped bottom with a depth of 50 cm in the middle and 30 cm on the sides. Two sheets of plastic were placed at the bottom of each plot in order to isolate them from the water table, and a perforated drain was placed on top of these plastic covers (Figure 1). Plots were then filled with the excavated soil (St-Nicolas schist loam) and laser graded to obtain a 5% slope at the surface. Kentucky bluegrass (*Poa pratensis* L.) was then sodded on the plots. In order to accelerate the effects of not fertilizing turfgrass for the control plots, sod was obtained from adjacent plots that had not been fertilized for five years. In addition to grasses (30% Kentucky bluegrass, 15% sheep fescue, 15% colonial bentgrass), control plots contained about 20% clover and 20% of other broadleaf weeds (dandelion, plantain, orange hawkweed, etc.).

Fig. 1: Excavated plot with the two plastic sheets and the drain used to collect leachate.

In each plot, we installed three capacitance soil moisture probes (Decagon Devices Inc., Pullman, WA, USA), at depths of 10, 20 and 30 cm and one soil temperature sensor, at a depth of 10 cm. The probes were all connected to a data logger (Decagon Em-5b) that registers soil readings every hour. In order to collect runoff water, we placed a 4" ABS pipe with a slit at the surface of the soil in the lowest part of the plot (Figure 2). The result was that each plot had two water collection pipes: one for leachate (through the perforated drain) and one for runoff (from the PVC pipe). Water flow from these two sources was measured by placing a tipping bucket (TB1L flow gauge, Hydrological services Pty Ltd, Warwick Farm, NSW, Australia) hooked to a data logger (Hobo Pendant UA-003-64, Onset Computer Corporation, Bourne, MA, USA) under each pipe. A water sample from each tip was collected, and pooled samples from tips in each plot were collected every day and analyzed for nutrient content (NO_3-N, NH_4-N, total P, total dissolved P, and dissolved reactive P). Total N and ammonium-N were measured by colorimetry (adapted procedure from NKONGE and BALANCE, 1982) while nitrate-N was measured using single column ion chromatography (Waters Corporation method B-1101, Waters Corporation, Milford, MA, USA). Total P content was determined by a sulfuric acid-persulfate digest of the unfiltered water samples adapted from ROWLAND and HAYGARTH (1997). Soluble P (organic and inorganic) was quantified from filtered (0.45 µm) water samples following procedures described by MURPHY and RILEY (1962) and VAZ et al., (1992). Dissolved organic P (DOP) values were calculated from the results of those analysis (DOP = DTP-DRP).

Fig. 2: Slit ABS pipe placed at the lowest part of the plots to collect runoff water.

Treatments application began in the spring of 2012. Five treatments were evaluated as a completely randomized design with three replicates. The three fertilized treatments were based on industry practices (treatment 1 and 2) and on a typical city by-law currently in place in Québec (treatment 3). We also included two unfertilized treatments, one with some maintenance practices applied (aeration, topdress, overseed) and the other one with no maintenance.

Specific treatments were:

1. Synthetic fertilizer: 20-0-12 (made from urea, polymer and sulfur coated urea and KCl, Envirosol Inc., St-Michel, Qc, Canada) with 50% slow-release N (1.5 kg N / 100 m^2

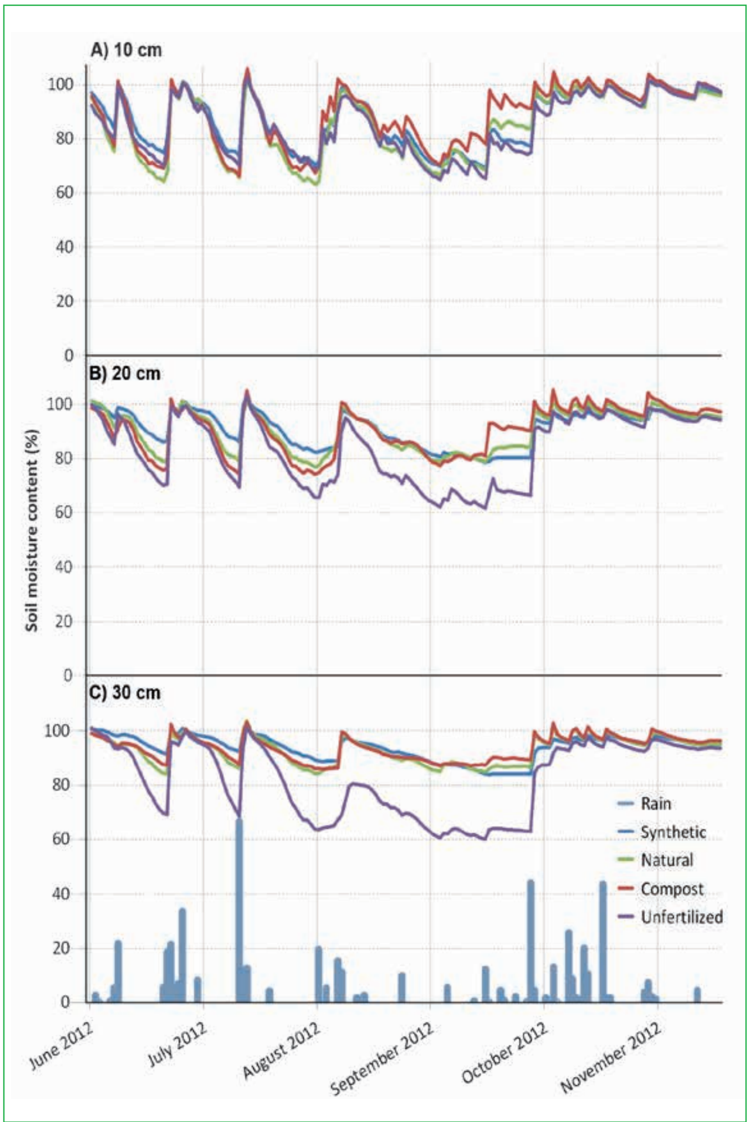

Fig. 3: Soil water content (% of field capacity) at three depths (10, 20 and 30 cm) in the research plots throughout the 2012 growing season.

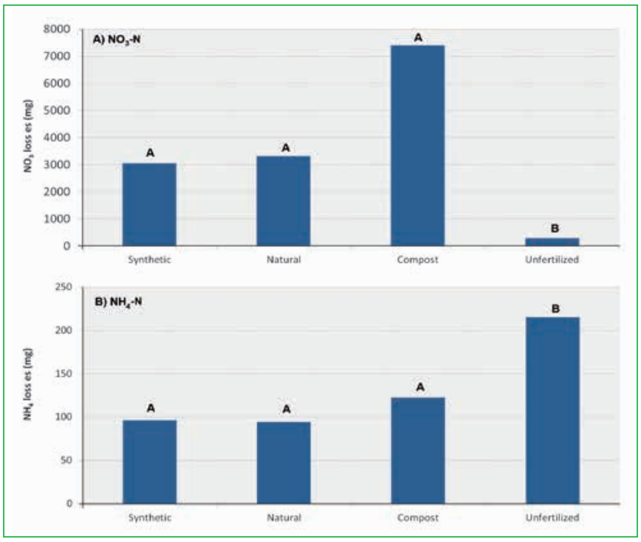

Fig. 4: Total nitrogen losses from the experimental plots during the 2012 growing season in A) nitrate-N and B) ammonium-N. Columns with the same letter are not statistically different.

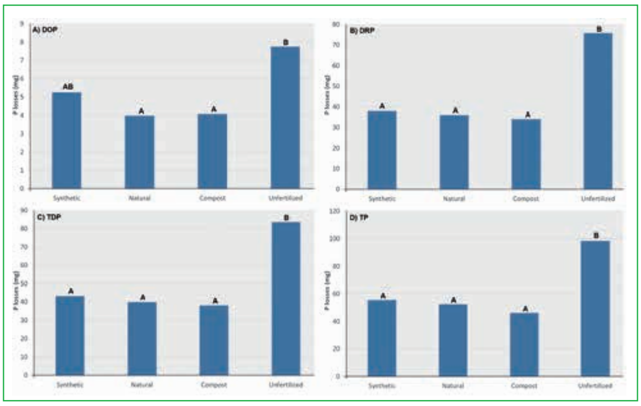

Fig. 5: Total phosphorus load in runoff water during the 2012 season. Column with the same letters are not significantly different. (DOP = dissolved organic P, DRP = dissolved reactive P, TDP = total dissolved P and TP= total P). Columns with the same letter are not statistically different.

/ yr) split in four applications (May, June, August, September).

2. Natural fertilizer: 9-2-5 (made from blood, feather and bone meal and potassium sulphate, Envirosol Inc., St-Michel, Qc, Canada) applied at 1.5 kg N / 100 m^2 / yr split in four applications (May, June, August, September).

3. Compost: 1.8-1-0.9 (Sea compost, Fafard Inc., Saint-Bonaventure, Qc, Canada) applied at 1.5 kg N / 100 m^2 / yr all at once in May

4. Unfertilized with maintenance

5. Unfertilized control

Plots were irrigated with overhead sprinklers in order to prevent turf dormancy by applying 2,5 cm of water once per week during drought periods. We calibrated the irrigation system to make sure each plot received the same amount of water during the irrigation events. We also evaluated turfgrass visual quality monthly on a 1 to 9 scale (1 = low quality, 9 = high quality, 6 = acceptable quality).

Results

Preliminary results from this project (full results from 2012 and partial results from 2013) show that few significant differences were observed for the different variables among the fertilized treatments. However, turfgrass fertilization did influence soil water content, runoff and leaching volume, and nutrient losses.

The 2012 growing season was exceptionally dry in Québec city. We did observe significant differences in soil moisture content, especially at depths of 20 and 30 cm. Fertilized plots (regardless of treatment) had a consistently higher soil water content compared to unfertilized plots (Figure 3). Some of these differences are likely due to the type of cover (i.e. Kentucky bluegrass sod vs mixed species cover). In 2013, precipitation was more abundant, and these differences were not observed (data not shown).

No differences between treatments were observed in runoff volume during both years, but grass fertilized with synthetic fertilizer had a lower leachate volume than other plots in 2012. Results from water sample analyses for 2013 are currently not fully available, but during the 2012 season, fertilizing plots resulted in higher nitrate-N losses, but lower ammonium-N losses than unfertilized plots through leaching (Figure 4). However, fertilized plots retained more phosphorus than unfertilized plots and had less runoff during that same season (Figure 5). On average, we estimate that losses in P from unfertilized plots were twice as high when compared to fertilized plots. Fertilizer source did not influence nutrient losses, either through leaching or runoff, in 2012.

Conclusion

Preliminary results from this experiment indicate that turfgrass fertilization does not significantly contribute to water contamination. An increase in NO_3 losses through leaching was observed in fertilized plots, but the average nitrate concentration measured over the season (3 mg L^{-1} NO_3-N) was more than 3 times below the Québec threshold criteria for potable water (10 mg L^{-1}). Furthermore, fertilized turfgrass reduced P load to water bodies by almost 50% when compared to unfertilized turf. While no differences were observed between the different fertilizer sources to date, we hope to continue this experiment during 4 more years in order to better measure long term changes in soil nutrient content and N and P losses through runoff and leaching.

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