

BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Achieving sustainable turfgrass management

Edited by Professor Michael Fidanza, Pennsylvania State
University, USA



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Contents

Series list	xii
Introduction	xxi
Acknowledgements	xxvii

Part 1 Physiology, breeding and cultivation

1	Advances in understanding turfgrass physiology	3
	<i>David Jespersen, University of Georgia, USA; Benjamin Wherley, Texas A&M University, USA; and Michelle DaCosta, University of Massachusetts Amherst, USA</i>	
1	Introduction	3
2	Drought stress	4
3	Heat stress	10
4	Freezing stress	16
5	Salt stress	23
6	Conclusion and future trends	28
7	Where to look for further information	28
8	References	28
2	Advances in breeding for improved cultivars of turfgrass	45
	<i>Phillip L. Vines, University of Georgia, USA; Ambika Chandra, Texas A&M AgriLife Research, USA; and Trent M. Tate, GO Seed, Inc., USA</i>	
1	Introduction	45
2	Breeding of cool-season turfgrasses	49
3	Breeding of warm-season turfgrasses	68
4	Conclusion and future trends	82
5	Where to look for further information	83
6	Appendix	84
7	References	86

3	Advances in soil management for successful establishment and maintenance of turfgrass	107
	<i>Douglas J. Soldat and Paul L. Koch, University of Wisconsin, USA</i>	
1	Introduction	107
2	Soil physical properties	109
3	Soil chemical properties	113
4	Soil biological properties	115
5	Conclusion and future trends	119
6	Where to look for further information	120
7	References	120
4	Advances in phosphite utilization for turfgrass	123
	<i>John Dempsey, Independent Turfgrass Research, Ireland</i>	
1	Introduction	123
2	Phosphite vs. phosphate	124
3	Phosphite use in turfgrass	125
4	Phosphite as a source of phosphorus nutrition	126
5	Phosphite and turfgrass nutrition	126
6	Disease control in turfgrass with phosphite	139
7	Conclusion and future trends	151
8	Where to look for further information	152
9	References	152
5	Advances in irrigation and water management of turfgrass	157
	<i>Marco Schiavon, Fort Lauderdale Research and Education Center, University of Florida, USA; and Matteo Serena, United States Golf Association, USA</i>	
1	Introduction	157
2	Estimating turfgrass water needs	159
3	Advances with sprinkler devices and technologies	163
4	Subsurface drip irrigation	165
5	Alternatives to potable water	167
6	Turfgrass management practices	172
7	Use of plant growth regulators	175
8	Soil surfactants	178
9	Conclusion and future trends	182
10	Where to look for further information	184
11	References	185
6	Advances in maintenance practices of turfgrass	197
	<i>Adam W. Thoms, Iowa State University, USA; and Alex J. Lindsey, University of Florida, USA</i>	
1	Introduction	197

	2 Mowing	199
	3 Putting green management	204
	4 Renovation	213
	5 Turf colorants	221
	6 Conclusion and future trends in research	222
	7 Where to look for further information	224
	8 References	224
7	Advances in turfgrass for athletic fields and sports pitches <i>Gerald M. Henry, University of Georgia, USA</i>	233
	1 Introduction	233
	2 Turfgrass species and cultivar selection	233
	3 Establishing sports fields	238
	4 Sports field maintenance	241
	5 Performance testing and site-specific management	248
	6 Conclusion	252
	7 Where to look for further information	252
	8 References	252
8	Advancements in turfgrass for ornamental lawns <i>Rebecca Grubbs Bowling, Texas A&M University, USA; and Joseph Young, Texas Tech University, USA</i>	261
	1 Introduction	261
	2 Advancements in turfgrass breeding and selection for ornamental lawns	265
	3 Advancements in sustainable ornamental lawn management	268
	4 Non-traditional or alternative lawns	273
	5 Socioenvironmental research to advance sustainable lawn management	276
	6 Conclusion and future trends	277
	7 Where to look for further information	277
	8 References	278
 Part 2 Biotic and abiotic stresses		
9	Advances in turfgrass disease management <i>James Kerns, North Carolina State University, USA</i>	289
	1 Introduction	289
	2 Anthracnose	291
	3 Dollar spot	295
	4 Microdochium patch and snow molds	298
	5 Brown patch of cool-season turfgrasses and large patch of warm-season turfgrasses	299
	6 Root diseases of turfgrasses	301
	7 Host resistance	302

8	Fungicide management	303
9	Conclusion and future trends	305
10	Where to look for further information	305
11	References	306
10	Advances in turfgrass insect pest management <i>Benjamin A. McGraw, Audrey Simard and Garrett Y. Price, Pennsylvania State University, USA</i>	311
1	Introduction	311
2	Recent studies of major insect pests	312
3	Recent studies on emerging turf pests	317
4	Advances in integrated pest management	319
5	Conclusion	328
6	Where to look for further information	331
7	References	331
11	Advances in turfgrass weed management <i>Matthew T. Elmore, Rutgers University, USA; Aaron J. Patton, Purdue University, USA; Travis W. Gannon, North Carolina State University, USA; and James T. Brosnan, University of Tennessee, USA</i>	339
1	Introduction	339
2	Current knowledge and future outlook for integrated weed management strategies	346
3	Current knowledge of integrated chemical and nonchemical management	363
4	Barriers to integrated weed management among practitioners and how to address them	369
5	Conclusion and future trends	373
6	Where to look for further information	374
7	References	374
12	Advances in plant growth regulation in turfgrass <i>David Gardner and Ed Nangle, The Ohio State University, USA</i>	389
1	Introduction	389
2	Growth regulation	391
3	Enhancing rooting and establishment	396
4	Enhancing wear tolerance	398
5	Seedhead suppression and seedhead production	399
6	Suppression and control of annual bluegrass	403
7	Enhancing disease tolerance	406
8	Enhancing tolerance to environmental extremes	408
9	Enhancing shade tolerance	412
10	Case study: how turf species and light quality determines effectiveness of using plant growth regulators for shaded turf	414

11	Conclusion and future trends	416
12	Where to look for further information	416
13	References	417
13	Advances in abiotic stress management in turfgrass <i>Charles Fontanier, Oklahoma State University, USA; and Chrissie A. Segars, Texas A&M University, USA</i>	427
1	Introduction	427
2	Approaches to sustainable abiotic stress management	428
3	Detecting abiotic stress and data-driven decision-making for managing abiotic stress	439
4	Conclusion and future trends	442
5	Where to look for further information	443
6	References	443
14	Advances in managing organic matter in turfgrass ecosystems <i>Alec Kowalewski, Charles Schmid, Ruying Wang and Emily Braithwaite, Oregon State University, USA</i>	451
1	Introduction	451
2	Monitoring and measuring organic matter in turfgrass	453
3	Organic matter and turfgrass diseases	456
4	Organic matter and soil microbial populations	457
5	Organic matter management practices	457
6	Conclusion	462
7	Where to look for further information	462
8	References	463
15	Advances in biostimulants in turfgrass <i>Michael Fidanza, Pennsylvania State University, USA; Cale Bigelow, Purdue University, USA; Stanley Kostka, Pennsylvania State University, USA; Erik Ervin, University of Delaware, USA; Roch Gaussoin, University of Nebraska-Lincoln, USA; Frank Rossi, Cornell University, USA; John Cisar, Cisar Turfgrass Research Service, USA; F. Dan Dinelli, North Shore Country Club, USA; John Pope, Pope Soils Consulting and Counseling Services, USA; and James Steffel, Lehigh Agricultural and Biological Services, USA</i>	469
1	Introduction	469
2	Classification of biostimulants for turfgrass	471
3	Considerations with the use of biostimulants for sustainable turfgrass management	488
4	Conclusion and future trends	490
5	References	492

Part 3 Case studies

16	Considerations with using unmanned aircraft systems in turfgrass	505
	<i>Dale J. Bremer, Kansas State University, USA; Dana G. Sullivan, TurfScout, LLC, USA; Phillip L. Vines, University of Georgia, USA; David McCall, Virginia Polytechnic Institute and State University, USA; Jing Zhang, University of Georgia, USA; and Mu Hong, Colorado State University, USA</i>	
	1 Introduction	505
	2 Brief overview of light reflectance by plants	506
	3 Critical mission planning	508
	4 Data processing considerations	513
	5 Examples of small unmanned aircraft system applications in turfgrass	515
	6 Conclusion and future trends	528
	7 Where to look for further information	530
	8 References	530
17	Considerations with selecting turfgrass varieties and cultivars	539
	<i>Kevin Morris, National Turfgrass Evaluation Program, USA; Yuanshuo Qu, Rutgers, The State University of New Jersey, USA; Len Kne, University of Minnesota, USA; and Steve Graham, University of Minnesota, USA</i>	
	1 Introduction	539
	2 Factors that impact turfgrass sustainability	541
	3 Utilizing National Turfgrass Evaluation Program data to select appropriate cultivars	544
	4 The updated National Turfgrass Evaluation Program database	546
	5 Case studies in selecting sustainable cultivars	548
	6 Conclusion and future trends	562
	7 Where to look for further information	565
	8 References	565
18	Considerations with turfgrasses and pollinators	567
	<i>Michelle Wisdom and Michael Richardson, University of Arkansas, USA; and Paige Boyle, Utah State University, USA</i>	
	1 Introduction	567
	2 Land use change and pollinator decline	568
	3 Pollinators in the landscape	570
	4 Urban grasslands as sources of pollinator habitat and forage	572
	5 Plant selection	575
	6 Management of pollinator-friendly mixtures	582
	7 Additional considerations	584

8	Conclusion and future trends	585
9	Where to look for further information	586
10	References	587
19	Considerations with water for turfgrass in arid environments <i>Brian Whitlark, United States Golf Association, USA; Kai Umeda, University of Arizona, USA; Bernhard R. Leinauer, New Mexico State University, USA; and Matteo Serena, University of California-Riverside, USA</i>	599
1	Introduction	599
2	Soil moisture	600
3	Case studies	608
4	Conclusion	620
5	Acknowledgements	621
6	Where to look for further information	621
7	References	622
20	Considerations with soil testing in turfgrass <i>Cole Thompson, United States Golf Association, USA; Elizabeth Guertal, Auburn University, USA; Pauric McGroary, Waypoint Analytical, USA; Douglas Soldat, University of Wisconsin-Madison, USA; and Bryan G. Hopkins, Brigham Young University and Soil Science Society of America, USA</i>	625
1	Introduction	625
2	Soil testing	626
3	A case study in sustainable soil test interpretation	633
4	Conclusion and future trends	640
5	References	643
	Index	647

Introduction

Turfgrass is required to meet a challenging range of aesthetic, functional and environmental requirements, whilst also mitigating the threat of abiotic and biotic stresses which are being accentuated by climate change. The turfgrass industry is also facing increasing pressure to reduce its environmental impact and advance more sustainable maintenance practices that utilise and/or optimise fewer agronomic-related resources. This volume summarises the wealth of recent research that addresses these challenges, whilst also identifying potential mitigation strategies to reduce the sector's contribution to climate change, such as reduced fertiliser use and water conservation.

The chapters are split into three parts: Part 1 chapters focus on the physiology, breeding and cultivation of turfgrass species, specifically focusing on breeding techniques, soil management, phosphite utilisation and irrigation and water management. Chapters in this part also draw attention to maintenance practices of turfgrass as well as advances in using turfgrass for athletics fields, sports pitches and ornamental lawns. Chapters in Part 2 review various biotic and abiotic stresses that affect turfgrass management, such as diseases, insect pests and weeds. Chapters also look at the importance of plant growth regulation, abiotic stress management, organic matter management and the use of biostimulants in turfgrass. Part 3 chapters provide case studies on various management practices for turfgrass, such as the use of unmanned aircraft systems, methods for selecting turfgrass varieties and cultivars as well as water management and soil testing.

Part 1 Physiology, breeding and cultivation

The volume opens with a chapter that focuses on understanding turfgrass physiology. Chapter 1 first begins by discussing physiological responses to four of the most common abiotic stress conditions: drought, heat, freezing and salinity stresses. The chapter reviews the importance of understanding how turfgrasses respond to drought, heat, freezing and salt stress, highlighting the historical perspectives and recent advances in each form of stress. The chapter also emphasises how these stresses damage plants and how in turn plants respond to tolerate these conditions. Sections on emerging issues and future directions for research for each form of stress are also provided.

The next chapter focuses on advances in breeding for improved cultivars of turfgrass. Chapter 2 draws attention to major cool-season species such as bentgrass, fine and tall fescue, Kentucky bluegrass and perennial ryegrass. It focuses on major warm-season species such as bermudagrass, buffalograss,

seashore paspalum, St. Augustinegrass and Zoysiagrass. For each species, the chapter discusses biological characteristics, traditional breeding strategies, current breeding objectives and advanced breeding methods for the major cool- and warm-season turfgrass species. Emerging challenges and future potential areas to develop research in are also highlighted.

The subject of Chapter 3 is advances in soil management for successful establishment and maintenance of turfgrass. It first explores soil physical properties relevant to turfgrass management, focusing specifically on soil texture, compaction, water-holding capacity and structure. The chapter then moves on to examine soil chemical properties relevant to turfgrass management, such as sodicity and plant-available nutrient content. This is then followed by an analysis of some of the most well-known soil biological properties crucial for turfgrass management, drawing specific attention to nitrogen availability and the importance of the soil microbiome. The chapter concludes by identifying areas for future study in soil management for turfgrass species.

Chapter 4 focuses on advances in phosphite utilisation for turfgrass. The chapter begins by first describing the chemical structure of both phosphate and phosphite and how the differences between them can affect their use as a nutrient source in plants. It moves on to review the use of phosphite in turfgrass and how it is an emerging nutrient source and is considered in some cases, controversial. The chapter goes on to examine how phosphite can be used as a source of phosphorus nutrition and highlights how it can be incorporated into turfgrass nutrition strategies. A section on disease control in turfgrass via phosphite is also included, before concluding with an overview of the importance of expanding currently available research in phosphite use in turfgrass management.

The next chapter looks at advances in irrigation and water management of turfgrass. Chapter 5 reviews the importance of estimating turfgrass water needs. With this in mind, the chapter moves on to examine advances with sprinkler devices and technologies as well as the importance of using subsurface drip irrigation as an alternative way to provide turfgrass with water. The chapter also provides alternatives to potable water and highlights several turfgrass management practices that can also reduce water needs, such as mowing, fertilisation, soil surfactants and plant growth regulators. This then leads into the next section, which focuses on the use of plant growth regulators in turfgrass management. The chapter also highlights the use of soil surfactants in turfgrass to manage soil hydrophobicity.

The subject of Chapter 6 is advances in maintenance practices of turfgrass. It begins by highlighting the importance of maintaining turfgrass quality through the use of mowing, drawing specific attention to various technologies and maintenance strategies such as autonomous mowers, vertical mowing and grooming. The chapter moves on to examine putting green management,

looking at aspects such as cultivation practices, rolling and firmness measurement. A section on turfgrass renovation is also provided, focusing on elements such as weed control, seed bed preparation, non-chemical control and other plant and soil issues that can occur during turfgrass renovation. The chapter also reviews the use of turf colourants and highlights how their application can be a useful tool for maintaining turfgrass.

Chapter 7 examines advances in turfgrass breeding and genetics for the purpose of athletic fields and sports pitches. The chapter first discusses the most appropriate types of species and cultivar for this, focusing on how improvements can be made to both warm-season and cool-season turfgrass. The chapter then discusses the different methods that can be used in order to improve the sports field's quality, such as alternative root zone amendments, seed coating and seed germination covers, hybrid turfgrass systems and thick cut sod. A section on sports field maintenance is also provided, drawing attention to aspects such as cultivation, topdressing, irrigation, grow lights and cooling fans as well as painting techniques. The chapter also reviews performance testing and site specific management.

The final chapter of Part 1 addresses the advancements in turfgrass for ornamental lawns. It first focuses on breeding and selection advances, drawing attention to consumer lawn preferences and the implications this can lead to in terms of contemporary breeding and production, as well as discussing the current breeding and selection trends for ornamental turfgrass lawns. The chapter then moves on to review various management practices, such as soil preparation, planting and establishment, fertilisation and nutrient management, mowing and cultivation and irrigation and water management. A section on non-traditional or alternative lawns is also provided, which is then followed by a review of socioenvironmental research practices to advance sustainable lawn management.

Part 2 Biotic and abiotic stresses

Part 2 opens with a chapter that covers advances in turfgrass disease management. Chapter 9 begins by first introducing one of the most destructive diseases of cool-season turfgrasses, anthracnose. The chapter first highlights how this disease's severity is influenced by plant nutrition, mowing, irrigation and sand topdressing and how it is crucial to develop these management practices to decrease the effect and occurrence of anthracnose in cool-season turfgrass. The chapter moves on to address dollar spot, a disease that affects all turfgrass species and how cultural management practices can provide more effect management of dollar spot. The presence of *Microdochium* patch and snow moulds are also touched upon, followed by brown patch, large patch and root diseases of turfgrasses. A section on host resistance is also included,

a recently developed disease management strategy for turfgrass ecosystems. This is then followed by an overview of fungicide management, in particular, the previously addressed dollar spot. The chapter concludes by highlighting where future research developments should turn their attention to.

Moving on from Chapter 9, Chapter 10 addresses the advances in turfgrass insect pest management. It starts by first reviewing the recent studies of major turfgrass insect pests, such as annual bluegrass weevil, bill bugs, white grubs and fall armyworm. The chapter then moves on to discuss recent studies on emerging turfgrass pests, focusing specifically on European crane flies and *Chaetocnema minuta*. A section on integrated pest management practices is also provided, drawing attention to methods such as pest detection and monitoring, chemical control, insecticide resistance and non-target issues with chemical insecticides. The chapter also discusses biological control, cultural control, host plant tolerance and resistance to pests and the use of plant growth promoting rhizobacteria.

The next chapter focuses on advances in turfgrass weed management. Chapter 11 discusses relevant and recent developments in synthetic herbicides, alternatives to synthetic herbicides and non-chemical strategies for weed management including cultural, physical, and genetic approaches. Advances in integrated weed management strategies and barriers preventing adoption of integrated weed management strategies are also discussed. Opportunities for research and development to improve integrated weed management are presented throughout.

Chapter 12 examines advances in plant growth regulation in turfgrass. It begins by providing an overview of the current use of growth regulators in both cool-season and warm-season turfgrass species. It then goes on to discuss enhancing rooting and establishment as well as turfgrass wear tolerance. A section on seed head suppression and production is also included, which is then followed by an overview of the suppression and control of annual bluegrass. Enhancing disease tolerance and tolerance to environmental extremes such as cold and drought are also discussed. Shade tolerance enhancement is also reviewed and a case study on how turfgrass species and light quality can determine the effectiveness of using plant growth regulators for shaded turf is also included.

The subject of Chapter 13 is advances in abiotic stress management in turfgrass. Commonly observed abiotic stresses in turfgrass systems include drought, high temperature, low temperature, low irradiance, traffic, salinity, and chemical phytotoxicity. Managing abiotic stresses with reduced irrigation, fertilizer, energy, and pesticides has become critical to the sustainability of the turfgrass industry. The chapter first describes how sustainable strategies and practices can be implemented to manage abiotic stress, focusing specifically on managing turfgrass growth, moderating the environmental conditions

causing the stress, improving abiotic stress tolerance and masking abiotic stress through methods such as colourants. It moves on to discuss ways of detecting abiotic stress and how data-driven decision-making can be used to manage it.

Chapter 14 focuses on advances in managing organic matter in turfgrass ecosystems. The chapter begins by first discussing the effects of organic matter on turfgrass, then moves on to review how organic matter can be monitored and measured. It then discusses the relationship between organic matter and turfgrass diseases, focusing on how different levels of organic matter can increase or decrease the development of major diseases such as dollar spot. The chapter also draws attention to soil microbial populations can affect organic matter content.

The final chapter of Part 2 addresses the advances in biostimulants in turfgrass. Chapter 15 reviews the use of biostimulants in turfgrass management. It first identifies the different types of biostimulants that can be used for turfgrass, focusing on phytohormones, biopolymers, protein hydrolysates and other nitrogen-containing compounds, botanical and synthetic bioactive compounds. The chapter also highlights the possibility of using humic substances, organics, inorganics/minerals, biologicals/microbials, soil surfactants and other naturally derived or synthetic bioactive compounds.

Part 3 Case studies

The first chapter of the four case study chapters in this section focuses on the use of unmanned aircraft systems in turfgrass monitoring. Chapter 16 begins by providing a brief overview of light reflectance by plants and how this can be used by sensors to assess how well a plant can utilise this for photosynthesis. The chapter moves on to emphasise the importance of mission planning in terms of using these systems, specifically indicating that defining the target of interest, how much resolution is required to identify patterns via an image, selecting the appropriate sensor and aircraft are all crucial elements to this process. Flight planning and data collection frequency are also deemed important as well. It also reviews data processing considerations and provides examples of small unmanned aircraft system applications in turfgrass.

Chapter 17 discusses selecting turfgrass varieties and cultivars, using the National Turfgrass Evaluation Program (NTEP) as a basis for the chapter's discussion. The chapter first describes the factors that impact turfgrass sustainability, then moves on to highlight how the data collected from using the NTEP can be used to select appropriate cultivars. An overview of the updated NTEP database is also provided, which is then followed by six case studies demonstrating ways of selecting sustainable cultivars via the use of the NTEP. These case studies include: identifying a geographical region, the use of seasonal analysis, choosing appropriate site characteristics, identifying key

sustainability factors, locating and comparing cultivars and finally, the advanced selection of cultivars with improved drought resistance.

Chapter 18 examines the potential relationship between turfgrasses and pollinators. The chapter begins by first considering how land use change and pollinator decline correlate with one another, specifically drawing attention to the drastic change in human population which in turn, has resulted in the need to significantly change the landscape. The chapter then considers how the presence of pollinators can be influenced by this changed landscape, followed by a section that considers using urban grasslands as sources of pollinator habitat and forage. This is then followed by a review of the various plants that can be used as part of turfgrasses for pollinator habitats, again, a case study is provided to support the discussion. The chapter also reviews the management of pollinator friendly mixtures, focusing specifically on how turfgrass management practices such as mowing and the use of pesticides need to adapt in order to support pollinators. A section on the additional considerations that also need to be taken into account when preparing turfgrass for pollinator species is also included.

The next chapter considers the management of water for turfgrass in arid environments. Chapter 19 first reviews the importance of soil moisture for turfgrass, focusing on methods to improve moisture uniformity such as deep watering, soil moisture monitoring, supplemental irrigation and the use of wetting agents. Several case studies are provided to emphasise the importance of water and irrigation management, the first three focus on how turfgrass conversion can result in significant water savings. The next two draw attention to the use of native grasses and alternative plant materials following turfgrass removal. The use of subsurface drip irrigation on golf courses is also discussed.

The final chapter of the book looks at using soil testing in turfgrass management. Chapter 20 addresses how soil testing can be used to analyse soil types, it first highlights the common soil test extractants used, such as Bray P1 and P2, Mehlich 1 and 3, Olsen (also known as sodium bicarbonate), Morgan, Lancaster, ammonium acetate and diethylenetriaminepentaacetic acid. The chapter also includes discussion on the use of monocalcium phosphate and saturated paste extract, before moving on to highlight how soil test calibration can be used as a basis for fertiliser recommendations. A case study in sustainable soil test interpretation is also included.

Acknowledgements

It is my pleasure to express my sincere gratitude and appreciation to all the authors and co-authors of each chapter in *Achieving sustainable turfgrass management*. These contributors are the leading experts in their discipline, and this textbook represents the first concentrated effort and focus on sustainability in turfgrass science applicable for academia, government, industry, and the practitioner. Also, I am grateful to Burleigh Dodds Science Publishing (Cambridge, United Kingdom) for their diligence and professionalism throughout the entire process, and for their willingness to include turfgrass science for their sustainable series in agricultural science.

Michael Fidanza, Ph.D.
Professor of Plant and Soil Science
Pennsylvania State University
Reading, Pennsylvania
USA

Chapter 1

Advances in understanding turfgrass physiology

*David Jespersen, University of Georgia, USA; Benjamin Wherley, Texas A&M University, USA;
and Michelle DaCosta, University of Massachusetts Amherst, USA*

- 1 Introduction
- 2 Drought stress
- 3 Heat stress
- 4 Freezing stress
- 5 Salt stress
- 6 Conclusion and future trends
- 7 Where to look for further information
- 8 References

1 Introduction

From a highly managed and well-manicured golf course putting green to a low-input right-of-way, turfgrasses must cope with a wide range of environmental extremes, which frequently fall outside of optimal growing conditions. These challenging environments can alter a plant's basic physiology, negatively impacting growth and development, and eventually result in the death of turf areas. Unfortunately, there is reason to believe that in the coming future environmental conditions in which turfgrasses are grown will only become more challenging. Global climate change is estimated to raise air temperatures by more than 2°C, and beyond elevated temperatures, and there is expected to be more extreme weather patterns of every sort, from floods to droughts (IPCC, 2021). Further compounding these issues is an increasing need to reduce inputs applied to turf areas for both environmental and economic reasons. This is particularly true of water resources, which are increasingly limited and in competition for demand from other users, but is also true of fertilizers, pesticides, and even the labor needed to implement cultural management practices.

The development of more sustainable turfgrasses relies on a better understanding of plant physiological response to stressful conditions, which includes determining how plants are damaged from specific stresses and the mechanisms employed to protect and prolong survival under stress. In turn, this information will help inform best turfgrass management practices, identify traits to integrate into advanced cultivars, and ultimately leverage new technologies that allow for the continuing use of functional green spaces despite these environmental challenges. This chapter will examine four of the most detrimental abiotic stress that turfgrasses commonly encounter (i.e. drought, heat, freezing, and salinity stresses) and which are expected to increase in duration or severity in the future.

2 Drought stress

2.1 Overview and significance of drought stress in turf

Turfgrasses are a major component of urban green spaces throughout the world. In addition to esthetic, recreational, and functional benefits, turfgrasses offer many important ecosystem services which benefit humans and the environment (Beard and Green, 1994; Chang et al., 2021). However, in regions where rainfall is not adequate to meet plant demand, turfgrasses may require supplemental irrigation to maintain acceptable quality and function. Although the exact acreage of irrigated turfgrass in the USA is not known, total turfgrass acreage has been estimated to be 30 million acres, making it three times larger than any other single irrigated crop (Milesi et al., 2005). In more arid parts of the USA, more than 50% of residential water usage is sometimes devoted to landscape irrigation (Degen, 2007; Haley et al., 2007; Mayer et al., 1999). Based on conservative estimates by Cabrera et al. (2013), total water use by golf courses combined with landscapes in Texas represented 47% of the total use within the urban/municipal water sector and 13% of the total annual demand by all activities, positioning urban irrigation as the state's third largest water user behind agriculture and other urban uses.

In recent years, water conservation has become a major priority for many municipalities, driven largely by urban population growth combined with periodic droughts (WHO, 2020). While urban landscapes have traditionally been comprised predominantly of turfgrass, municipalities and water purveyors are increasingly providing homeowners monetary incentives to remove turfgrass and replace it with alternative 'water-efficient' landscapes utilizing native or locally adapted alternative plant species (Addink, 2005; Pincetl et al., 2019). Another water conservation strategy employed by water purveyors is mandatory irrigation restrictions, which may limit residential landscape irrigation to a given day of the week or, under more extreme measures, restrict irrigation once every 2 weeks or less (Hejl et al., 2021). In addition to residential irrigation restrictions,

larger turf sites such as golf courses or athletic fields are also commonly forced to deal with reduced water allocations imposed by water purveyors as a means of meeting water conservation goals (GCSAA, 2015). When this occurs, turf managers must prioritize water to critical areas such as greens and tees or impose deficit irrigation on larger acreage areas such as fairways in order to meet or remain in compliance with water allocation goals. For turfgrasses to remain a sustainable component of future urban green spaces, they must be capable of providing functional surfaces with significantly less water in the form of rain or irrigation than in the past and, at times, surviving extended periods of prolonged drought.

Considering the importance and widespread use of turfgrasses in the modern landscape and growing need for water conservation, turfgrass drought resistance has become a trait of major importance within the industry. As a result, a substantial amount of plant physiological research and breeding efforts are currently being devoted to this issue. The following is intended to provide a review of the current understanding of turfgrass drought resistance while highlighting recent advances which have improved our knowledge in this area.

2.2 Historical perspectives, recent advances and future direction with drought stress research in turf

Drought develops when root zone soil moisture becomes insufficient to support turfgrass water demand. Therefore, drought is most common during periods of high evapotranspiration and low rainfall or inadequate irrigation. The ability of turfgrass plants to resist drought, termed drought resistance, is a broad classification involving one or multiple drought-resistance mechanisms, including avoidance, tolerance, or escape.

2.3 Drought avoidance in turfgrasses

Drought avoidance is considered to be the most widely employed drought-resistance mechanism among turfgrasses (Levitt, 1980). Avoidance is characterized by the ability of a turfgrass plant to maintain favorable internal water potential and normal physiological function during drought, primarily by minimizing transpiration and/or maximizing water uptake. Turfgrass species noted for possessing superior drought-avoidance characteristics include tall fescue [*Lolium arundinaceum* (Schreb.) SJ Darbysh.], bermudagrass [*Cynodon dactylon* (L.) Pers.], buffalograss [*Bouteloua dactyloides* (Nutt.) J.T. Columbus], and bahiagrass [*Paspalum notatum* Flueggé] (Fry and Huang, 2004).

Considering nearly 98% of water uptake by turfgrass roots is lost to transpiration through leaves, species and cultivars capable of minimizing

Index

- 2,4-D, phenoxy herbicide 341, 344, 350
- ABA. *see* Abscisic acid (ABA)
- Abiotic stress management xxiv, 168
- approaches 428-429
 - improving tolerance 433-438
 - managing growth 429-430
 - masking 438-439
 - moderating environmental conditions 430-433
 - description 427
 - detecting and data-driven
 - decision-making 439-442
 - future trends 442-443
 - goals 428
 - plant stress response 427-428
 - tools 438
- Abiotic stress tolerance 360, 363, 403, 433, 481, 482
- biostimulants and soil health 435
 - designed stress response 435-438
 - development of alliance, low input
 - sustainable turf 434
 - genetic improvement 434
- Abscisic acid (ABA) 6, 7, 178, 471, 474
- ABW. *see* Annual bluegrass weevil (ABW)
- Acetolactate synthase (ALS)-inhibiting herbicides 344
- Acetyl CoA carboxylase (ACCCase)-inhibiting herbicides 344
- Acibenzolar-S-methyl (ASM) 436-437, 479
- Acidovorax avenae* 407
- Adopt widespread conversion 585
- Agrostis* 52, 54, 55, 314, 326
- Aliette® 139
- A-LIST approved cultivars 48
- Allelopathy 362, 363
- Alliance for Low Input Sustainable Turf (A-LIST) 236
- Alternaria alternata* 142
- Amicarbazone 346, 404
- Amino acids 20, 82, 476-477
- Ammonium acetate 629, 639, 640
- Analysis of variance evaluating effects 562
- Annual bluegrass control 217, 219, 346-348, 353, 357, 358, 364, 403-406
- Annual bluegrass weevil (ABW) 312-314, 320, 321, 325, 326, 525
- Anthracnose 114, 139, 140, 151, 207, 212, 296, 301, 357, 415, 456
- agronomic practices 294
 - ball roll-facilitating practices 293
 - basil rot anthracnose 293
 - cultural management program 292
 - foliar anthracnose 293
 - incidence 291
 - NE-1025 and NE-1046 multistate projects 291
 - nitrogen (N) and potassium (K) deficiencies 292
 - qualitative measurement practices 294
 - sand topdressing 294
 - severity 291, 292
 - sustainable management of 295
- AquaGro 179
- ASM. *see* Acibenzolar-S-methyl (ASM)
- Athletic fields and sports pitches
- cooling fans 245-246
 - cultivation practice 241-243
 - environmental impacts 233
 - grow lights 245-246
 - hybrid turfgrass systems 240
 - irrigation 243-245
 - long-term management challenges 239
 - open-spoon aeration 242
 - painting techniques 246-247
 - performance testing 248-251
 - professional sports field, USA 233, 234
 - root zone amendments 238-239
 - seed coating 239-240
 - seed germination covers/blankets 240
 - site-specific management 251-252
 - sodding 238, 240
 - sprigging 238
 - thick cut sod 240-241
 - topdressing 243

- Autonomous mowers 202–203
 Auxins 348, 474
 Average green percent coverage 560
 Azoxystrobin 368
- Bacillus thuringiensis galleriae* 324
- Bacterial etiolation of creeping
 bentgrass 407, 415
- Basic cation saturation ratio (BCSR) 631,
 632
- Bentgrass
 AFLP markers 54
 annual bluegrass 127–129
 biological characteristics of 52–54
 colonial bentgrass 52, 53
 creeping bentgrass 53, 357, 358, 407,
 415
 disease resistance breeding 54
 DNA marker technology 54
 genetic diversity 54
 interspecific hybridization 54
 multiple genetic linkage maps 55
 phenotypic and genotypic recurrent
 selection 54
 RAPD markers 54
 south German Mixed Bentgrass 52
 velvet bentgrass 53
- Bermudagrasses
 benefits and limitations 71
 biological characteristics 68–69
 cadmium tolerance 72
C. dactylon var. *dactylon* 71
 ‘Champion’ bermudagrass 177
 DNA marker technologies 72
 hybrid bermudagrass cultivars 524
 intra- or interspecific hybridization
 breeding strategies 69, 71
 ‘IronCutter’ hybrid bermudagrass 234,
 235
 ‘Latitude 36’ hybrid bermudagrass 234
 ‘Northbridge’ hybrid bermudagrass 234
 ‘Princess 77’ bermudagrass 174, 411
 progeny stability 71
 ‘Riviera’ bermudagrass 399
 ‘Tahoma 31’ hybrid bermudagrass 234
 ‘TifEagle’ bermudagrass 177, 395
 ‘TifGrand’ hybrid bermudagrass 235
 ‘TifSport’ bermudagrass 395
 ‘TifTuf’ hybrid bermudagrass 234, 266,
 267
 ‘Tifway’ bermudagrass 176, 234, 395,
 397, 408, 412
 for vegetative cultivars 69, 70
- Big data management 528–529
- BioCORE Elite Shoe-Surface Tester 249
- Biological herbicides 352–354
- Biostimulant Industry Workgroup
 (BIW) 491–492
- Biostimulants xxv, 124, 125, 137, 138, 141,
 170, 174, 435
 classification of 471–473
 biological/microbials 481–482
 biopolymers, protein hydrolysates
 and nitrogencontaining
 compounds 476–479
 botanical/synthetic bioactive
 compounds 479
 humic substances 479–480
 inorganic/minerals 481
 naturally derived/synthetic bioactive
 compounds 487
 organics 480–481
 phytohormones 471–476
 soil surfactants 482–487
 considerations, sustainable use 488–489
- The European Biostimulant Industry
 Council (EBIC) 470–471
- future trends 490–492
- The Merriam-Webster Dictionary 469
- metabolic enhancers 470
- plant biostimulant 470
- Biotic stress tolerance 360, 363, 403, 434,
 474, 481, 482
- Bispyribac-sodium 217
- BIW. see Biostimulant Industry Workgroup
 (BIW)
- Bluemuda 236, 237
- Bray P1 627
- Bray P2 627
- Breeding 265–268, 434, 521–524
 of cool-season turfgrasses (see Cool-
 season turfgrasses)
 DNA-based genetics and genomics
 methods 48
 and genetics xxiii
 high-throughput plant phenotyping
 methods 48, 49
 next-generation DNA sequencing
 technologies 49
 quantitative trait locus (QTL)
 mapping 48
- Brinkman traffic simulator 399
- Broadleaf weed control 339
- Brown patch 299–300

- Buffalograss 73-75, 268
- Calibration 513-514, 626, 631-632
- Canopy temperature 519
- Carbon fixation process 12
- Carbon-to-nitrogen (C:N) ratio 115-116
- 'Cash for grass' programs 273
- Catch-can method 243
- Chaetocnema minuta* xxiv, 318-319
- 'Champion' bermudagrass 177
- Chemical characteristics of soils 634
- Chemical eradication 404
- Chemical indicators 113
- Chinch bugs 327
- Chitin 478
- Chlorophyll fluorescence 13
- Chlorophyll metabolism 12
- Chlorothalonil 316
- Chlorpyrifos 321
- CitraZoy™ 81
- Clariireedia* 296
- Clegg Impact Surface Tester 212, 214, 248, 249
- Climate warming 22
- Clothianidin 323
- 'Cobalt' St. Augustinegrass 266
- Cold temperature stress 432
- Cold tolerance 408-409
- Colletotrichum cereale* 140, 142, 291
- Colonial bentgrass 52, 53
- Colorants 438-439
- Combustion temperature 455
- Commercial software 523
- Conidial germination 145
- The Conservation Foundation 277
- Considerations selecting, varieties and cultivars
- Consumer lawn preferences 265-266
- Cool-season turfgrasses xxi, xxiv, 15, 18, 25, 170, 173, 174, 180, 236-238, 262, 263, 346
- bentgrass 52-55
- brown patch 299-300
- carpetgrass 7
- cooperative turfgrass breeders test (CTBT) 7
- descriptions of 45, 46
- fine fescues 55-59
- genotypic and phenotypic recurrent selection approach 50, 51
- high freezing tolerance 22
- irrigation and water management 158, 159
- Kentucky bluegrass 50, 59-63
- osmoprotectants 26
- perennial ryegrass 63-65
- plant growth regulators (PGRs) 392-393
- Plant Variety Protection Act 49
- seed production 45, 47
- tall fescue 65-67
- Cooperative and collaborative testing programs 47
- Cooperative turfgrass breeders test (CTBT) 47
- Creeping bentgrass 53, 357, 358
- Crocus* spp. 582
- Cultivation practices 458-461
- Cultural practices 583
- Cynodon dactylon* 69, 71-73
- Cytokinins 474-475
- Daconil Action fungicide 410
- Dandelion art and images 339
- Dead spot 360, 361, 525, 526
- Deep and infrequent irrigation strategy 601
- Demethylation inhibitors (DMI) fungicides 406, 407
- 'Diamond' zoysiagrass 414
- Diethylenetriaminepentaacetic acid (DTPA) 629-630
- Digital image analysis (DIA) 522-523
- Disease management 118, 143, 479, 481
- anthracnose 291-295
- brown patch 299-300
- dollar spot 295-298, 303-305, 482
- fungal strains and biotypes identification 289
- fungicide management 303-305
- host resistance 302-303
- large patch 300
- microdochium patch 298-299
- root diseases 301-302
- snow mold 298-299
- strategies/principles 290
- Distributions of original and transformed water consumption data 562
- Distribution uniformity (DU) 600-601
- Dollar spot xxiii, 295-298, 303-305, 347, 406
- Drought-resistance mechanisms 5-10
- Drought stress 266, 267
- drought avoidance 5-8

- drought tolerance 8-10, 266, 267, 409-412
 water conservation 4, 5
 DryJect 242
 Dry sand injection 206
 DTPA. *see* Diethylenetriaminepentaacetic acid (DTPA)
 DU. *see* Distribution uniformity (DU)
- EBIC. *see* European Biostimulant Industry Council (EBIC)
 Ecosystem services 4, 261, 264, 272, 274, 275, 567-569, 572, 574, 586
 Elec-Trak 201
 Endophytes (E+) 327, 328
 Entomopathogenic nematodes (EPNs) 324
 Ethylene 475-476
 European Biostimulant Industry Council (EBIC) 490
 European species of crane flies (ECFs) 317-318
 Evapotranspiration 6
 Evapotranspiration (ET)-based irrigation controllers 244
 Exogenous applications 7, 437, 438, 470, 476
- Fairway sand topdressing 607
 Fairy ring 301
 Fall armyworm caterpillar (FAW) 316-317
 'Feel' and visual observations 440
 FieldScout TruFirm 212, 213
 Fine fescues 9, 27, 169, 209, 268, 327, 360
 biological characteristics 55-57
 breeding objectives 58
 hard fescue transcriptome 59
 inter simple sequence repeat (ISSR) markers 58
 mowed progeny plot trials 58
 phenotypic and genotypic recurrent selection 58
 single-nucleotide polymorphism (SNP) markers 59
 Fixed-wing/multicopter aircrafts 511-512
 'Floritam' St. Augustinegrass 77, 78, 398
 Flowering 'bee lawns' 274
 Flowering species support pollinators, mixed grass/forb lawns 577-578
 Flurprimidol 395, 404, 406, 407
 Forbs in bermudagrass lawns in Arkansas, USA 581
 Fosetyl-Al 139, 140
- Fraise mowing 208-209, 217
 Freezing stress
 cold acclimation conditions 18-21
 deacclimation sensitivity 22, 23
 energy requirements 21
 freeze-test protocols 19
 freezing tolerance 17-23
 infrared thermal imaging 17
 laboratory-based freezing tests 19
 mechanical stress 17
 molecular mechanisms 21
 omics technologies 20
 osmotic stress 17
 quantitative trait loci (QTL) 21
 transcriptomic and proteomic approaches 20
 Freezing tolerance 17-23
 Fungicide management xxiv, 303-305
- GA₃-inhibiting growth regulators 412
 General sufficiency levels 637
 Gibberellic acid (GA) 476
 Global climate change 3
 Global position satellite (GPS) technology 244
 Goosegrass control 347
 Graden sand-injection system 242
 Gray leaf spot suppression 407
 Green management xxii
 Growing degree day (GDD) models 315, 392, 393, 396
 Growth management
 growing degree day (GDD) models 430
 mowing 429
 overapplication of PGRs 429-430
 plant growth regulators (PGRs) 429-430
- H₂O₂ generation 148-151
 Halophytic turfgrass saltwater couch grass 25, 26
 Handheld sampling 250
 Hand watering 605
 Healthy soils 108
 Heat shock proteins 13, 14
 Heat stress
 C3 photosynthetic pathways 11
 C4 photosynthetic pathway 11
 carbon metabolism 11-13
 cultural management practices 15
 elevated root zone temperatures 11
 environmental conditions 11
 fatty acid metabolism 14-15

- overview of 10-11
- protein metabolism 13-14
- Heat-tolerant hybrid bluegrass 15
- Herbicide Resistance Action Committee, 2021 346
- Herbicides
 - 2,4-D, phenoxy herbicide 341, 344
 - acetic acid herbicide solutions 373
 - acetolactate synthase (ALS)-inhibiting herbicides 344
 - acetyl CoA carboxylase (ACCCase)-inhibiting herbicides 344
 - biological herbicides 352-354
 - corn gluten meal 352
 - dandelions control 340, 359
 - dinitroaniline herbicides 345
 - dislodgeable herbicide 350
 - exposure risk assessments 349
 - foliar transferable residue dissipation studies 349
 - mechanism of action 341-345
 - microtubule assembly-inhibiting herbicides 344
 - natural products 346
 - nonchemical practices 345
 - organic and alternative herbicides 350-352
 - pharmaceutical inhibitors 346
 - primary consequence of 344
 - PSII-inhibiting herbicides 345
 - registered herbicides 344
 - resistance development 345
 - synthetic herbicide 346-350
 - topramezone herbicide 364
- Hobby gardeners 266
- Hollow-tine aerification 205
- Host resistance 302-303
- Hybrid bermudagrass cultivars 524
- Hydraulic conductivity 6
- Hydrogen peroxide 147
- Hydrophobicity 178, 179
- Hydrophobic/water-repellent soils 431
- Hyperspectral sensors 511

- IAA. see Indole-3-acetic acid (IAA)
- Illinois soil N test 116
- Image calibration 513-514
- Image overlapping 512
- Indole-3-acetic acid (IAA) 474
- Industry and university plant-breeding programs 234
- Innovation® 81

- Insect pest management xxiv
 - Billbugs* (*Sphenophorus* spp.) 314-315
 - biological control 311, 323-325
 - biorational controls 311
 - Chaetocnema minuta* 318-319
 - chemical controls 312, 321-322
 - chemical insecticides 322-323
 - cultural controls 325-326
 - defense mechanisms 329
 - European species of crane flies (ECFs) 317-318
 - fall armyworm caterpillar (FAW) 316-317
 - host plant resistance 326-328
 - host plant tolerance 326
 - insecticide resistance 322, 330
 - Listronotus maculicollis* 312-314
 - pest detection and monitoring 319-320
 - plant growth-promoting rhizobacteria (PGPRs) 328
 - pollinator insecticide 323
 - tolerance/damage thresholds 311
 - in turfgrass ecosystems 328, 329
 - white grubs 315-316
- Integrated digital data hub 529
- Interpreting soil nutrient tests for fertilizer recommendations 632
- 'IronCutter' hybrid bermudagrass 234, 235
- Irradiant solar energy 506
- Irrigation and water management xxii, 601
 - best practice irrigation scheduling 159
 - climate parameters 160
 - for cool-season turfgrasses 158, 159
 - deficit irrigation 160
 - electrical conductivity (EC_w) 167
 - environmental conditions 158
 - ET-based irrigation controllers 161
 - ET_c level 160
 - evapotranspiration (ET_o) calculation 160
 - evapotranspiration (ET) measurement functionality 157-158
 - evapotranspiration (ET) rates 157
 - intensified management practices 159
 - irrigation sensors 162
 - leaching fraction (LF) 168, 169
 - management practices 158
 - ornamental lawns 272-273
 - plant growth regulators 175-178
 - potable water 167-172
 - salinization issues 167
 - 'set and forget' irrigation scheduling 159
 - short crop reference evapotranspiration (ET_{os}) 160

- smartphone-friendly controller 162, 163
 soil moisture sensors (SMS) 161, 162
 soil surfactants 178-182
 sprinkler devices and
 technologies 163-165
 subsurface drip irrigation 165-167
 during summer 158
 turfgrass management
 practices 172-175
 for warm-season species 158, 159, 166,
 169, 170
 Irrigation water use 620

 Japanese beetles 316

 KCl treatment 134
 Kentucky bluegrass 7, 50, 177, 236, 272
 asexual reproductive mechanism 60
 biological characteristics 59
 genetic diversity 62
 hybrid-based Kentucky bluegrass
 breeding 60, 61
 machine-assisted automated
 pollination 60
 progeny testing 62
 sexual fertilization 60
 transcriptome analyses 63

 Lancaster 629
 'Latitude 36' hybrid bermudagrass 234
 Lawn care operator (LCO) 372
 The Lawn Institute 277
 Lazer® 81
 Leaching fraction (LF) 168, 169
 'Lights out' technique 218
 'Lobo' zoysiagrass 266
 Localized dry spots (LDS) 178
 Iowa's Integrated Roadside Vegetation
 Management program 574
 Low-precipitation portable sprinklers 606
 Low soil pH locations sorted by Table
 Avg from results across five
 locations 554

 Maintenance practices xxii, 584-585
 mowing 199-204
 putting green management (see Putting
 green management)
 renovation 213-221
 turf colorants 221-222
 Market segmentation 265
 Mehlich 1 627-628

 Mehlich-3 extractant method 293, 628
 Metabolic dysfunction 14
Metarhizium brunneum 324
 'Meyer' zoysiagrass 401
 Microbial insecticides 324
Microcystis aeruginosa (Kützing) 136
Microdochium nivale infection
 in vitro suppression 142-146
 phosphite-mediated
 enhancement 146-151
 phosphite suppression of 140-141
 Microdochium patch xxiii, 141, 149,
 298-299

 Minimum levels for sustainable nutrition
 (MLSN) 631-632, 635-636
 Mixed grass and forb lawns 580
 MLSN. see Minimum levels for sustainable
 nutrition (MLSN)
 Moderating environmental conditions
 430
 drought stress mitigation 430-432
 low-temperature stress
 mitigation 432-433
 salinity stress mitigation 432
 traffic stress mitigation 433
 Moisture uniformity (MU) 600-601
 Monocalcium phosphate 630
 Morgan 629
 Mowed spaced-plant nurseries 52
 Mowing 583
 autonomous mowers 202-203
 double mowing 202
 early mower machines 199-200
 Elec-Trak 201
 electric garden tractor 201
 electric mowers 201
 flail mowers 200-201
 frequency 202
 grooming 203-204
 maintenance recommendations 202
 mechanical mower 200
 ornamental lawns 271-272
 reel mowers 200, 201
 rotary mowers 200
 single mowing 202
 vertical mowing 203
 zero-turn mowers 201, 202
 MU. see Moisture uniformity (MU)
 Multispectral sensors 510-511

 Narrow spectral wavebands 521
 National Academy of Sciences 290

- National cool-season water use/drought tolerance test entries and sponsors (2016) 558
- National Turfgrass Evaluation Program (NTEP) xxv, 237, 266, 434, 539-540
 updated database 546-548
 utilization 544-546
- Native pollinating insects 572
- NDRE. *see* The Normalized difference red edge (NDRE)
- NDVI. *see* Normalized difference vegetation index (NDVI)
- Nearinfrared (NIR) region 506, 508
- Neonicotinoids 321
- New Jersey NTEP trial 237
- NIR. *see* Nearinfrared (NIR)
- Nitrate leaching 174, 181
- Nitrogen availability 115-117
- Nitrogen cycle 115
- Nitrogen (N) fertilization 117, 173, 174, 347, 356, 359, 518, 583
- Nonchemical control of annual bluegrass 219
- Non-mowed spaced-plant nurseries 52
- Non-traditional/alternative lawns
 'bee lawns' 274
 benefits 275
 biodiversity 274
 'cash for grass' programs 273
 flowering 'bee lawns' 274
 'grass-free' lawns 274
 'pollinator lawns' 274
 runoff volume 275
 urban stream syndrome 276
 water retention 275
- The Normalized difference red edge (NDRE) 441
- Normalized difference vegetation index (NDVI) 250, 410, 440-441, 508, 517-518
- 'Northbridge' hybrid bermudagrass 234
- Northeastern Weed Control Conference, 1948 340
- NTEP. *see* National Turfgrass Evaluation Program (NTEP)
- Olsen (sodium bicarbonate) 628-629
- OM management. *see* Organic matter (OM) management
- Oregon NTEP trial 238
- Organic Materials Research Institute (OMRI) 351
- Organic matter (OM) management xxv, 115, 451
 monitoring and measuring
 fixed soil core depth 454
 implication of verdure removal 455
 LOI method 455
 soil sampling methods 453-454
 thatch thickness 453
 variable depth sampling 454-455
 practices 457
 accumulation problem 457-458
 cultivation 458
 grooming equipment 459
 hollow tine- or solid tine-cultivated areas 458-459
 injection equipment 459
 non-destructive 461-462
 PlanetAir and Hydroject 460
 sand-based systems 457-459
 sand topdressing 458
 Thatch-X 462
 United States Golf Association recommendations 458
 vertical mowing 459
 saturated hydraulic conductivity (K_{sat}) 172, 452
 and soil microbial populations 457
 synopsis 462
 thatch accumulation 451
 and turfgrass diseases 456-457
- Organophosphates 321
- Ornamental lawns xxiii
 abundance and diversity 262, 264, 276
 breeding and selection trends 266-268
 clipping management 271
 compost materials 269
 consumer lawn preferences 265-266
 cultural practices 268
 environmental concerns 270
 fertilization and nutrient management 270-271
 high phosphorus-containing fertilizers 270
 irrigation and water management 272-273
 mowing 271-272
 natural turfgrass in park 262, 263
 non-traditional/alternative lawns 273-276
 nutrient analysis 270
 public lawns 261
 seed coatings 270

- socioenvironmental research 276-277
 soil preparation 269-270
 soil testing 271
 supplemental N 271
 US lawn cover 262, 264
 Osmoprotectants 26
 Osmotic adjustment (OA) 9, 10
 Overhead sprinklers/sub-surface drip irrigation 430
- Paclobutrazol 405-407, 410, 414
 Paspalum species 525
Paspalum vaginatum 401
 'Penncross' creeping bentgrass 53, 414
 Perennial ryegrass 12, 14, 17, 18, 20-27, 48, 50, 63-65, 111, 133, 134, 139, 169, 175, 176, 178, 214, 216, 217, 219, 237-239, 299, 318, 393, 394, 397-399, 402, 403, 405, 407-410, 436, 437, 477, 481, 541, 604
 Perennial weed control 348
 Pest Control Products Act, 2003 350
 Pest management practices xxiv
 Pest scouting 328
 Pheromone-based monitoring programs 320
Phoma macrostoma 353
 Phosphate conversion in planta
 accumulation of phosphite in turfgrass tissues 130-132
 phosphorus-deficiency responses 133-138
 on root zone phosphorus accumulation 132-133
 Phosphite-based fungicides 139
 Phosphite utilization xxii
 in avocado 126
 biological/non-biological oxidation 126
 on creeping bentgrass and annual bluegrass 127-129
 foliar treatment 127
 Fosetyl-Al or aluminum tris (O-ethyl phosphonate) 125
 K_3PO_3 126
 leaf accumulations 129
 Microdochium nivale infection 140-151
 oomycete pathogens preventative treatment 125
 oxidation and reduction 123
 vs. phosphate 124-125
 phosphate conversion in planta 130-138
 phosphoric acid (H_3PO_4) 123
 positive effects of 124
 potassium phosphite 125
 symplastic ambimobility 130
 Phosphorus fertilizer recommendations 638
 Photosynthetic photon flux density (PPFD) 440
 Physical weed management 354-356
 Phytohormones 435
Phytophthora cinnamomi 142
Phytophthora palmivora 142
 Phytoremediation strategy 397
 Plant-available nutrient 114
 Plant disease pyramid 297
 Plant disease triangle 297
 Plant growth-promoting rhizobacteria (PGPR) 328, 482
 Plant growth regulators (PGRs) xxiv, 391, 392
 agronomic practices 396
 classification 389-391
 cool-season turfgrass 392-393
 disease tolerance 406-407
 on golf courses 391
 growing degree day (GDD) model 392
 in *Poa annua* management and control 391
 rooting 396-398
 seedhead production 402-403
 seedhead suppression 399-402
 for shaded turf 414-416
 shade tolerance 412-414
 tolerance to environmental extremes 408-412
 trinexapac-ethyl (TE) 391-399, 401-403
 warm-season turfgrass 394-396
 wear tolerance 398-399
 Plant stress resistance 430
 Plant Variety Protection Act 49
 'Platinum TE' 235
Poa annua management and control 391, 400
 PoaCure® 347
 POGO TurfPro 249
 Pollinators xxvi, 567-568
 additional considerations
 beneficial predators 584
 lawn care options, conversions, and public education need 584-585
 future trends 585-586
 land use change and pollinator decline 568-570
 management of pollinator-friendly mixtures 582-584

- overview 567-568
- plant selection 575-582
 - home lawn in Utah 582
- pollinators landscape 570-572
- urban grasslands, sources of pollinator
 - habitat and forage 572-574
 - Ben Geren Park Golf Course 575
- Polysaccharides 478-479
- Postemergence herbicides 404
- Potassium fertilizer recommendations 641
- Potassium phosphite 125
- Precision agriculture 251, 329
- Preemergence herbicides 359
- Pre-processing phase, images 512
- 'Princess 77' bermudagrass 174, 411, 412
- Promoting mixed-species lawns 585
- Propiconazole 316
- ProVista™ grass 79, 361
- Pseudomonas fluorescens* 353
- Pure air injection machines 206
- Putting green management
 - cultivation 204-209
 - firmness measurement 212-215
 - practice measures 204
 - rolling 209-212
- Pythium root diseases 139, 301, 302

- Quality-weighted water consumptions 563
- Quantitative trait locus (QTL) mapping 48

- Raleigh 78
- Reclaimed water 245
- Reduction in water use 620
- Remote sensing 442, 505
- Renovation xxiii
 - definition 213
 - late fall sod installation 215
 - slice seeding 214, 215
 - spring or early summer sod
 - installation 215
 - timing for 213
 - weed control 216-218
- Residential and commercial lawns 574
- 'Riviera' bermudagrass 399
- Root diseases 301-302
- Root-to-shoot ratios 134, 137, 138

- Salt stress
 - hormone responses 26-27
 - ionic stress 24, 25
 - management practices 23
 - morphological adaptations 24-25
 - osmotic stress 23, 24
 - salinity tolerance 25, 27
 - salt bladder 25
 - saltwater intrusion 23
 - sodium transporters 25-26
- Sand and gravel injection cultivation 242
- Sand-capping 239
- Sand injection 205-206
- Sand topdressing 206-208
- SAR. *see* Systemic acquired resistance (SAR)
- Saturated paste extract (SPE) 630-631
- Scheduled irrigation 602
- Sclerotinia homeocarpa* 406
- Sclerotinia minor* 353, 364
- SDIs. *see* Subsurface drip systems (SDIs)
- Seashore paspalum 24-26, 47, 75-77, 113, 164-166, 170, 173, 174, 176, 177, 181, 218, 235, 267, 296, 303, 394, 396, 401, 402, 411, 412, 414, 437, 543, 617
- Seaweed extract (SWE) 474-475
- Seedbed preparation 219
- Seed production 45
- Selecting data for greenup, winter kill and drought tolerance parameters 555
- Sensor category 510
- Shade tolerance xxiv, 57, 58, 74, 80, 235, 412-414, 440
- Sheep grazing 198
- ShockWave 205, 206, 243
- ShortCUTT newsletter 371
- Silicon 437-438
- Single cultivar/experimental traits, bentgrass
 - sustainability 556
- SISIS AERAID system 242
- SLAN. *see* Sufficiency levels for available nutrients (SLAN)
- Small unmanned aerial systems (sUAS) 250
 - data collection protocols 508-509
 - red-green-blue image 518
 - spectral, red-green-blue (RGB), thermal measurements and vegetation indices 516-517
- Smith-Kerns model 304
- Snow moulds xxiii, 299
- Sodicity 113-114
- Sodium adsorption ratio (SAR) 114, 171
- Sod production industry 47
- Software service providers 515
- Soil amendments 111
- Soil characteristic selection, identify soil pH locations 554

- Soil compaction 110–111
- Soilless media 630
- Soil management xxii
 biological properties 107
 chemical properties 107
 health assessment 108, 109
 physical properties 107
- Soil microbiome 117–119
- Soil microorganisms 126
- Soil moisture xxvi
 meter 212, 215
- Soil moisture sensors (SMS) 161, 184
- Soil particle size classification systems 109,
 110
- Soil root zone properties 220–221
- Soil sampling depth 454
- Soil structure 111–113
- Soil surfactants 179
 AquaGro 179
 commercial wetting agents 180
 hydrophobicity 178, 179
 localized dry spots (LDS) 178
 penetrants 179, 181
 retainers 179, 181
 ‘split fairway’ demonstration 182, 183
 water resistance and retention 178
- Soil testing xxvi
 calibration and fertilizer
 recommendations 631–632
 extractants 626–631
 future trends 640–643
 overview 625
- Soil texture 109–110
- Soil water repellency 178
- Solventa Labile Available Nitrogen (SLAN)
 test 116
- South German Mixed Bentgrass 52
- SPE. *see* Saturated paste extract (SPE)
- Spectral reflectance signatures 506–507
- Sports Field Management Association 242
- Spray™ system 363
- Sprinkler devices and
 technologies 163–165
- St. Augustinegrass 182
 454 sequencing technology 79
 biological characteristics 77
 ‘Cobalt’ St. Augustinegrass 266
 embryo-rescue technology 78, 79
 ‘Floritam’ St. Augustinegrass 77, 78
 genetic diversity analysis 78
 illumina sequencing 78
 interploid hybrids 78
 ProVista® 79
 TamStar™ 78, 398
- ‘Stay-green’ traits 12
- Stellar 4GL 238
- Stomatal conductance 6
- Stomatal regulation 6
- Strategic fungicide applications 525–526
- sUAS. *see* Small unmanned aerial systems
 (sUAS)
- Subsurface drip systems (SDIs) 183,
 615–618
- Succinate dehydrogenase inhibitor (SDHI)
 fungicides 303, 304
- Sufficiency levels for available nutrients
 (SLAN) 631–632
- Summer patch 301
- Sustainable cultivars selection 548–550
 advanced selection, improved drought
 resistance 555–556
 evaluation of average quality during
 drought 556–559
 evaluation of quality-weighted water
 consumption 559–562
 choose appropriate site
 characteristics 552–553
 future trends 562–564
 facing future 564
 knowing past 564
 identify geographical region 550–551
 identify key sustainability factors 553
 locate and compare cultivars 553–555
 management impacts (*see* Sustainable
 management impacts)
 use of seasonal analysis 551–552
- Sustainable management impacts
 ability to respond 541–542
 abiotic factors 543
 geography 542
 integrated pest management (IPM) 541
 performance information 542
 pesticide use 542
 seasonal adaptation 543
 speed of germination 542
 top-performing species and cultivar 541
 use characteristics 541
 worldwide problem 542–543
- Sustainable soil test interpretation
 rational 633
 sample selection and
 description 633–635
 sufficiency levels and
 recommendations 635

- phosphorous 635-639
- potassium 639-640
- synopsis 640
- Sustainable turfgrass management 119, 430-431. *see also individual entries*
- SWE. *see* Seaweed extract (SWE)
- Syngenta ABW monitoring program 320
- Systemic acquired resistance (SAR) 436

- Table generating results 557
- Table quality ratings, two trial locations and mean 551
- 'Tahoma 31' hybrid bermudagrass 234
- Tall fescue 65-67
- 'TamStar' St. Augustinegrass 78, 398
- Tank mixing herbicides 346
- Thermal sensors 442, 511
- 'TifEagle' bermudagrass 177, 395
- 'TifGrand' hybrid bermudagrass 235
- 'TifSport' bermudagrass 395
- 'TifTuf' hybrid bermudagrass 234, 266, 267, 550-552
- 'Tifway' bermudagrass 176, 234, 395, 397, 408, 412
- Title 7 Code of Federal Regulations 351
- Topramezone herbicide 364
- Toro Precision Sense 6000 (PS6000) 250
- Total phenolic content (TPC)
 - accumulation 147-150
- Travel speed 512
- Trifloxystrobin 437
- Triticale* sp. defense system 147
- True color images 510
- Turfgrass breeders 434, 521-522
- Turfgrass cultivar field trials 523
- Turfgrass management 547
- Turfgrass Producers Association 278
- Turfgrass quality ratings
 - individual states 550
 - season 552-553
- Turfgrass rhizosphere
 - beneficial application, soil surfactant 487
 - description 483
 - exudates, mucilage and sloughed cells 484
 - illustration indicating processes and functions 485
 - illustration of root exudates
 - functioning 486
 - microbial activity 485
 - review of plant roots 483
 - root and root hair connectivity 486
 - root section illustration 484
 - root-soil interface 484
- Turfgrass Trial Explorer selection 540, 545, 547-549
- Turfgrass water conservation 434
- The 'Turfgrass Weed Control for Professionals' guide 371
- Turf-type perennial ryegrass 21

- Uncalibrated images 513
- United States Department of Agriculture's Natural Resource Conservation Service (USDA-NRCS) 108
- United States Golf Association
 - recommendations 458
- Unmanned aircraft systems xxv
 - applications
 - aerial vs. ground-based measurements 519-521
 - drought assessment and detection 515, 518-519
 - strategic cultivar selection, breeding programs 521-524
 - critical mission planning 508-509
 - data collection frequency 512-513
 - flight planning 512
 - resolution requirements 510
 - selection of appropriate sensors 510-511
 - selection of suitable aircraft 511-512
 - target of interest 509
 - data processing considerations
 - calibration 513-514
 - characteristics of, remote sensing data 513
 - image processing packages, research grade vs. edge-of-field 514-515
 - future trends 528-530
 - light reflectance by plants 506-507
 - benefits and limitations, vegetation indices 507-508
 - overview 505
 - predicting/managing pests 524
 - challenges, incidence maps development 527-258
 - mapping, aerial analysis 525-526
 - remote pest detection, sensing/aerial imagery 526-527
 - spatial distribution 524-525
- Urban lawns 572
- USDA National Organic Program 351

- US Department of Agriculture (USDA) 490-491
- U.S. Environmental Protection Agency 321
- US EPA Pesticide Environmental Stewardship Program 372-373
- Utility turf areas 573
- Vapor pressure deficits (VPDs) 8
- Vegetation indices (VIs) 507-508
- Velvet bentgrass 53
- Vertical takeoff and landing (VTOL) aircrafts 511-512
- Virginia NTEP trial 238
- VIs. *see* Vegetation indices (VIs)
- Visible light sensors 510
- Vredo Seeder 214, 216
- VTOL aircrafts. *see* Vertical takeoff and landing (VTOL) aircrafts
- Warm-season turfgrasses xxi, xxiv, 21, 22, 166, 169, 170, 173, 174, 176, 180, 218, 234-236, 327, 347, 348, 360, 401, 411, 432, 553
- bermudagrasses 68-73 (*see* Bermudagrasses)
- buffalograss 18, 73-75
- carpetgrass 7
- descriptions of 45, 46
- drought and salinity tolerance 68
- irrigation and water management 158, 159
- large patch 300
- plant growth regulators (PGRs) 394-396
- seashore paspalum 75-77
- seed production 45, 47
- St. Augustinegrass 77-79
- zoysiagrass 18, 22, 24-26, 79-82
- Water band index (WBI) 441
- Water conservation 4, 5
- Water for turfgrass, arid environments
- methods to improve moisture uniformity
- deep watering 601-603
- modify soil and improve drainage 606-607
- soil moisture monitoring 603-605
- supplemental irrigation 605
- wetting agents 605-606
- native grasses and alternative plant materials 610
- Briarwood Country Club, Camelback Golf Club and Wigwam Golf Club 610-613
- Camelback Golf Club - Ambiente Golf Course 613-615
- overview 599
- soil moisture 600
- uniformity 600-601
- subsurface drip irrigation, golf courses 615-618
- materials and methods 618-619
- results 619-620
- synopsis 620-621
- turfgrass conversion, water savings 608
- Biram Wood Golf Course 608
- Menlo Country Club 609
- The Preserve Golf Club 609-610
- Water-holding capacity 111
- Water-use efficiency (WUE) 272
- WaterWick machine 242
- WBI. *see* Water band index (WBI)
- Weak acid herbicides 348
- Wear tolerance xxiv
- Weedbine 355
- Weed conservation 574
- Weed management xxiv, 523-524, 574
- allelopathy 362
- broadleaf weed control 339
- clover 339
- cost barrier 372
- crabgrass 339
- cultural weed management 356-359
- decision support tools 371
- definition 339
- herbicides (*see* Herbicides)
- information sharing 369, 370
- integrated chemical and nonchemical management 363-368
- legislation 373
- nonchemical practices 340
- physical weed management 354-356
- professional lawn care operator (LCO) 372
- remote sensing and artificial intelligence 363
- research funding 369
- restrictions 369
- 'right-plant, right-place' approach 359, 360, 363
- ShortCUTT newsletter 371
- The 'Turfgrass Weed Control for Professionals' guide 371
- unwillingness 373
- Weed Science Society of America 340

-
- Weevil Trak^(SM) ABW monitoring program 320
- Wetting agents 431-432
- Wisconsin NTEP trial 238
- Xanthomonas campestris* 353
- Yellow nutsedge 370
- Zoysiagrass 9, 10, 18-22, 24-26, 47, 79-82, 169, 216, 217, 219, 221, 235, 236, 245, 267, 272, 300, 315, 327, 354, 360, 394, 401, 414, 437, 440, 459, 580, 604