TURFGRASS SCIENCE AND MANAGEMENT

Ma Huiling, Li Yuzhu and **V.R .Squires**
Gansu Agricultural University, Lanzhou, China

Keywords: History of turf culture, centers of origin, stoloniferous, rhizomatous, lawn mowers, propagation techniques, agronomy, plant breeding, hybrids, USDA, climatic zones, high traffic areas, pests and diseases, golf courses, sports arenas, lawns, Australia, Asia-Pacific, China, Japan, Korea, North America, South Africa, Europe

Contents

1. Overview of Turf and Turf Management as a Separate Discipline including the History of Turf and Turf Management
1.1. A Brief History of Turf Management
2. Role and Function of Turf
2.1. Turfgrass Functional Benefits
2.1.1. Soil Erosion Control and Dust Stabilization
2.1.2. Groundwater Recharge and Surface Water Quality
2.1.3. Organic Chemical Decomposition
2.1.4. Soil Improvement and Restoration
2.1.5. Heat Dissipation-Temperature Moderation
2.1.6. Noise Abatement and Glare Reduction
2.1.7. Decreased Noxious Pests, Allergy-Related Pollens, and Human Disease Exposure
2.1.8. Safety in Vehicle Operation-Equipment Longevity
2.1.9. Security for Vital Installations and Lower Fire Hazard
2.2. Turfgrass Recreational and Aesthetic Benefits
2.3. Turf Management has Emerged as a New and Expanding Discipline
3. Summary of the Characteristics of Typical Turf Species
3.1. Cool-Season Turfgrasses
3.1.1. Characteristics Compared with Warm-Season Turfgrasses
3.2. Warm-Season Turfgrasses
3.2.1. Characteristics Compared with Cool-Season Turfgrasses
4. Turf species used around the world — some examples
4.1. Asia - Pacific Region
4.2. North America
4.3. China
4.3.1. China's Principal Regions for Turf Culture
4.3.2. Selecting Turfgrass Seeds for the Climatic Zone
5. Turf Establishment
5.1. What are the Important Things to consider when Establishing a Lawn from Seed?
5.2. Establishing Turf by Vegetative Means (sod)
6. Maintenance of Turf
6.1. Soil Fertility and Plant Health
6.2. Why Weeds Invade Turf
6.3. Pesticide Contamination of Surface Water by Runoff
6.4. Unanticipated Detrimental Effects of Pesticides
7. Challenges, On-going Research and Future Priorities for Turf Management

7.1. The Investigation on Germplasm Resources of Turfgrass, Evaluation on Introduced Species of Turfgrass and Breeding Research
7.2. The Research and Utilization of Native and Wild Cover Plant Resources
7.3. The Research on Turf Establishment, Management and Quality Evaluation
7.4. The Development and Application of New Technology for Turf Establishment and Management
Related Chapters
Glossary
Bibliography
Biographical Sketches

Summary

Turf is a name given to plants (mostly grasses) that are able to form a sod that can be maintained at a height and density that is appropriate to the designated role. This is mostly defined as aesthetically pleasing, grassy landscapes that still act as functional groundcover under reasonably high pressure from foot traffic.

Turfgrass management is the study and science of grasses that are used in high traffic areas such as athletic fields, lawn tennis courts, bowling and croquet greens, cricket and football pitches and golf courses.

The main turf species in each of the broad climatic zones are described and their center of origin, agronomic attributes and principal strengths and weaknesses for different uses are outlined. Healthy turf requires good soil management and plant water relations. Aeration and other soil-related factors are vital to successful turf culture. Management of pests and diseases is also vital. Better propagation techniques and genetic improvement of turf species play an important role.

The field of turf management is very broad and includes seed and sod production, turfgrass establishment and maintenance in lawns, sports turf, parks, schools, and cemeteries, as well as golf courses. Turfgrass production and management has developed into an industry. This article examines important aspects of this industry with a focus on the management of plant species that are commonly used for turf.

1. Overview of Turf and Turf Management as a Separate Discipline Including the History of Turf and Turf Management

1.1. A Brief History of Turf Management

People the Mayan Empire, staged the violent games played with a ball in a grass-covered arena at least as early as the 5th century but people from northern Europe and eastern Asia probably invented the idea of the *lawn*, defined as ‘a field of cultivated and mowed *grass*’ Extensive areas of natural grasslands (meadows) were common throughout these regions and rhizomatous and stoloniferous grass species that were the dominant plants were pre-adapted to the close cropping that is a feature of lawns and turf.

The documented history of turfgrass for sport in European literature goes back to at least the 13th century with historical mentions of lawn bowling in the 1200s and to grassed cricket ovals in the early 14th century. Later, the idea of broad expanses of manicured grass had come to be accepted. By the 18th century in England and France, for example, many of the wealthy people had sweeping green lawns across their estates. Turfgrass is synonymous with lawn but refers to broader expanses of lawn as seen in sports arena, football stadia, horse racing courses and golf courses.

The earliest management practiced was probably rolling of the turfgrass to smooth playing fields. First stone, then iron rollers were used. Mowing came much later, after the invention of the mower in 1830 by Englishman Edwin Budding. Prior to that grazing animals or men armed with scythes got the grass under control.

Green, weed-free lawns so common today didn't exist in America until the late 18th century and in other places a little later. Instead, the area just outside the front door of a typical rural home was typically packed dirt or perhaps a cottage garden that contained a mix of flowers, herbs, and vegetables. Box 1 shows the place of origin of the principal turfgrass species.

Dr. James B. Beard wrote in *Turfgrass Science and Culture*, "The first investigations of turfgrasses and their culture in the United States were initiated around 1880 at the Michigan Agricultural Experiment Station by the noted botanist W.J. Beal." Bermudagrass (*Cynodon dactylon*) was introduced to the United States from Africa by 1751.The high growth rate of this genus provides it with rapid colonization in disturbed areas and quick recovery from traffic damage caused in sports activities. It was shown that if logarithmic growth rates could be sustained for 1 year (e.g., through ideal environment and frequent division), then it would be possible for 1 m^2 of grass to cover an area equal to 50% of the land area of the world.

Turfgrass species, including Bermuda grass, and mixture evaluation studies were conducted by the U.S. Department of Agriculture (USDA) and by scientists at Pennsylvania State University. By 1915, the USDA was collaborating with the U.S. Golf Association to find the right grass—or combination of grasses—that would create a durable, attractive lawn suitable to the variety of climates found in America.

Included in the testing were Bermuda grass (*Cynodon dactylon*) from Africa, blue grass (*Poa* spp. from Europe, and a mix of Fescues (*Festuca* spp.) and bent grass (*Agrostis* spp.). Fifteen years later, the USDA had discovered several grass combinations that would work in the various climate zones of USA .Similar breeding and selection work was proceeding in Australia and South Africa and elsewhere. At one time all the commercial seed of *Cynodon dactylon* used in the United States came from Australia (Tracy, 1917).

The right grass and the right treatments weren't the only problems facing those wanting the perfect lawn, however. There was also the challenge of providing sufficient water to keep the grass green in summer. Cutting the grass was a challenge, as well. Many lawns were trimmed with scythes, an expensive process that required a certain amount of finesse, or by grazing livestock on the greens.

Mechanical mowing came about early in the 19th century and there is a general agreement that an Englishman, Edwin Budding, an engineer at a textile mill, developed a cylinder, or reel-type mower. It was a series of blades arranged around a cylinder with a push handle patterned after a machine used in a cloth factory for shearing the nap on velvet.

2. Role and Function of Turf

According to Beard and Green, Turfgrass benefits may be divided into (i) functional, (ii) recreational, and (iii) aesthetic components (Table 1). Specific *functional benefits* include: excellent soil erosion control and dust stabilization thereby protecting a vital soil resource; improved recharge and quality protection of groundwater, plus flood control; enhanced entrapment and biodegradation of synthetic organic compounds; soil improvement that includes CO_2 conversion; accelerated restoration of disturbed soils, substantial urban heat dissipation-temperature moderation; reduced noise, glare, and visual pollution problems; decreased noxious pests and allergy-related pollens; safety in vehicle operation on roadsides and engine longevity on airfields; lowered fire hazard via open, green turfed firebreaks; and improved security of sensitive installations provided by high visibility zones. The *recreational benefits* include a low-cost surface for outdoor sport and leisure activities enhanced physical health of participants, and a unique low-cost cushion against personal impact injuries. The *aesthetic benefits* include enhanced beauty and attractiveness; a complimentary relationship to the total landscape ecosystem of flowers, shrubs and trees; improved mental health with a positive therapeutic impact, social harmony and stability; improved work productivity; and an overall better quality-of-life, especially in densely populated urban areas. For many centuries turfgrasses have played a vital role in protecting the environment, long before it became an issue of major national and international importance to modem societies. The turfgrass species now in use evolved during the past 50 million years and they have been cultured by humans to provide an enhanced environment and quality-of-life for >10 centuries.

FUNCTIONAL	RECREATIONAL	AESTHETICS
Soil erosion control Dust prevention Heat dissipation Noise abatement Glare reduction Air pollution control Nuisance animal reduction	Low cost surfaces Physical health Mental health Safety Spectator entertainment	Beauty Quality of life Mental health Social harmony Community pride Increased property values Compliments trees and shrubs in landscape

Table 1. Benefits of Turfgrasses

2.1. Turfgrass Functional Benefits

2.1.1. Soil Erosion Control and Dust Stabilization

Turfgrasses are relatively inexpensive, durable groundcovers that protect our valuable, nonrenewable soil resource from water and wind erosion. Agricultural operations and similar activities such as construction involve extensive land disruption, in contrast to turfed land areas, which are maintained in a long-term stable state.

Runoff water from agriculture and urban areas are important contributors to the nonpoint surface-water pollution affecting rivers and lakes. Sediment and nutrients account for a large percentage of the nonpoint surface-water pollution.

Quality turfgrass stands modify the overland flow process so that runoff is insignificant in all but the most intense rainfall events. The ability of grasses to function as vegetative filter strips that greatly reduce the quantity of sediment transported into surface streams and rivers is well documented, especially when positioned downslope of cropland, mines, and animal production facilities for surface soil stabilization, plus a high biomass matrix that provides resistance to lateral surface water flow, thus slowing otherwise potentially erosive water velocities. Therefore, perennial turfgrasses offer one of the most cost-efficient methods to control water and wind erosion of soil. Such control is very important in eliminating dust and mud problems around homes, factories, schools, and businesses. When this major erosion control benefit is combined with the groundwater recharge, organic chemical decomposition, and soil improvement benefits discussed below the resultant relatively stable turfgrass ecosystem is quite effective in soil and water preservation.

2.1.2. Groundwater Recharge and Surface Water Quality

One of the key mechanisms by which turfgrasses preserve water is their superior capability to trap and hold runoff, which results in more water infiltrating and filtering through the soil-turfgrass ecosystem. A mowed turfgrass possesses a leaf and stem biomass ranging from 1,000 to 30,000 kg ha-', depending on the grass species, season, and cultural regime. This biomass is composed of a matrix of relatively fine-textured stems and narrow leaves with numerous, random open spaces. The canopy matrix is porous in terms of the water infiltration capability.

A key characteristic of mowed turfgrasses that contributes to this very effective erosion control is a dense ground cover with a high shoot density ranging from 75 million to >20 billion shoots per hectare. Regular mowing, as practiced in turf culture, increases the shoot density substantially because of enhanced tillering when compared with ungrazed grasslands. Putting and bowling greens on golf links mowed at a 4-mm height possess up to 66 billion shoots ha^{-1}.

The reduced runoff volume from a turfgrass cover offers the potential to decrease the storm-water management requirements and costly structures used in urban development. Turfgrass ecosystems can support abundant populations of earthworms (*Lumbricidae*) of from 200 to 300 m^{-2}. Earthworm activity increases the amount of macropore space within the soil, which results in higher soil water infiltration rates and water-retention capacity.

2.1.3. Organic Chemical Decomposition

The runoff water and sediment that occurs from impervious surfaces in urban areas carries many pollutants, including metals such as Pb, Cd, Cu, and Zn; hydrocarbon compounds as from oil, grease and fuels; and household and industrial hazardous wastes such as waste oils, paint thinners, organic preservations, and solvents. Turfgrass areas can be designed for the catchment and filtration of these polluted runoff waters. It is significant that large populations of diverse soil microflora and microfauna are supported by this same soil-turfgrass ecosystem. Microflora constitute the largest proportion of the decomposer biomass of most soils. The bacterial biomass component ranges from 30 to 300 g m^{-2}, and fungi from 50 to 500 g m^{-2}, with actinomycetes probably in a similar range. Soil invertebrate decomposer biomass ranges from 1 to 200 g m^{-2}, with the higher values occurring in soils dominated by earthworms. Though soil animals play an important part in the decomposition process, only 10% or less of the CO_2 produced during decomposition has been attributed to them.

The bacterial population in the moist litter, grass clippings, and thatch of a turf commonly is in the order of 10^9 organisms cm^{-2} of litter surface. These organisms offer one of the most active biological systems for the degradation of trapped organic chemicals and pesticides.

There also is the gaseous dimension of atmospheric pollution control. Carbon monoxide (CO) concentrations >50 μL often occur in urban environments, especially near roadsides. Certain turfgrasses, such as tall rescue *(Festuca arundinacea*), may be useful as an absorber of CO from the urban environment.

2.1.4. Soil Improvement and Restoration

An extremely important function of turfgrasses is soil improvement through organic matter additions derived from the turnover of roots and other plant tissues that are synthesized in part from atmospheric CO_2 via photosynthesis. A high proportion of the world's most fertile soils has been developed under a vegetative cover of grass. The root depth potential ranges from 0.5 to 3 m, depending on the turfgrass species, extent of defoliation, and soil-environmental conditions. Generally, C_4 warm-season turfgrasses produce a deeper, more extensive root system than the C3 cool-season species.

The annual root system turnover rate is about 40% for a lawn. The amount of root biomass annually produced and turned over into the soil, or root net productivity, for a defoliated grassland is higher than the amount reported for ungrazed prairie ecosystem. Similarly, the net effect of regular mowing on prostrate growing turfgrasses would be to concentrate energies into increased vegetative growth, as opposed to reproductive processes, and to form a canopy of numerous dense, short, rapid growing plants with a fibrous root system. Accelerated soil restoration of environmentally damaged areas by planting perennial grasses is employed effectively on highly eroded rural landscapes, burned-over lands, garbage dumps, mining operations, and steep timber harvest areas. These areas may then be developed as parks, golf courses, sports field complexes, and recreational areas,

2.1.5. Heat Dissipation-Temperature Moderation

The overall temperature of urban areas may be as much as 5 to 7 ^{o}C warmer than that of nearby rural areas. Through the cooling process of transpiration, turfgrasses dissipate high levels of radiant heat in urban areas. The transpirational cooling effect of green turfs and landscapes can save energy by reductions in the energy input required for interior mechanical cooling of adjacent homes and buildings. An additional asset of a turfgrass ecosystem is the lower total energy input requirements for maintenance compared with other landscape types. Energy inputs for maintenance could be reduced by proper selection of resource efficient, sustainable species and cultivars of turfgrasses, trees, and shrubs.

2.1.6. Noise Abatement and Glare Reduction

The surface characteristics of turfgrasses function in noise abatement as well as in multi-directional light reflection that reduces glare. Studies have shown that turfgrass surfaces absorb harsh sounds significantly better than hard surfaces such as pavement, gravel, or bare ground. These benefits are maximized by an integrated landscape of turfgrasses, trees, and shrubs. The proper use of turfgrasses, trees, and shrubs in concert to maximize noise abatement is receiving more attention within the scientific community over recent years.

2.1.7. Decreased Noxious Pests, Allergy-Related Pollens, and Human Disease Exposure

Closely mowed residential lawns reduce the numbers of nuisance pests such as snakes (Ophidia spp.), rodents (Rodentia), mosquitoes (Culicidae spp.), ticks (Ixodoidea spp.; Acari order), and chiggers (Trombiculidae spp.; Acari order). As undesirable small animals seek haven in taller grasses, flowers, and shrubs at locations more distant from the house, they also are less likely to invade the house.

Allergy-related pollens can cause human discomfort and potentially serious health concerns to susceptible individuals. Dense lawns typically are void of the many weedy species that often produce allergy-related pollens. In addition, most turfgrasses that are mowed regularly at a low height tend to remain vegetative with minimal floral development, and thus have reduced pollen production; however, the best solution for those who enjoy outdoor gardening activities is to select turfgrass species and cultivars that do not form flowers nor the resultant allergy-related pollen. The turf cultural practices employed also influence flower and pollen production.

Exposure to a number of serious human diseases is facilitated by key insect vectors such as mosquitos and ticks. Of current concern is Lyme disease that is spread by a tick commonly found in unmowed tall grass and woodland-shrub habitats. A closely mowed lawn around residences offers a less favorable habitat for unwanted nuisance insects and disease vectors. Chigger mite (*Trombicula irritens*) population densities were found to be highest at the ecotone or transition area of neighboring 600-mm tall grass beyond the mowed turf. This is attributed to the distinct decrease in temperature and solar radiation at the ecotone.

2.1.8. Safety in Vehicle Operation-Equipment Longevity

Roadside turfgrasses aid in highway safety, as well as erosion control, by serving as a stabilized zone for emergency stoppage of vehicles. Mowed roadside turfs enhance line-of-sight visibility and views of signs and animal hazards, which are vital factors for operators of fast-moving vehicles. Turfgrasses are used for soil and dust stabilization around airport runways and taxiways to prolong the operating life of airplane engines. Furthermore, turfgrasses are used on small airstrips as a low-cost means to stabilize the runway surface.

2.1.9. Security for Vital Installations and Lower Fire Hazard

Expanses of green, low-growing turfs in the landscape provide a high visibility zone that discourages unwanted intruders and vandals. Such turfs offer a low-cost approach that is a viable security measure, especially around sensitive military, and police installations. Also, the low fuel value of green, prostrate-growing turfs serves a valuable function as a firebreak that significantly lowers the fire hazard if properly positioned. This attribute is especially important for homes and buildings adjacent to extensive woodland or brush areas.

2.2. Turfgrass Recreational and Aesthetic Benefits

Turfs provide a low-cost, safe recreational surface. Many outdoor sports and recreational activities utilize turfgrasses, including archery, badminton, baseball, cricket, croquet, field hockey, football, golf, hiking, horse racing, horseshoes, lawn bowling, lawn tennis, lacrosse, polo, rugby, shooting, skiing, soccer, softball, track and field, and volleyball.

Both the enjoyment and the benefits of improved physical and mental health derived from recreation and leisure activities on turfs are vital to contemporary society, especially in densely populated urban areas. Community pride and interest can be derived from quality sports fields and parks. Also, spectators derive entertainment from sporting competitions played on turfs.

Turfgrasses provide a unique, low-cost cushioning effect that reduces injuries to the participants when compared with poorly or nonturfed soils, particularly in the more active contact sports like football, rugby, and soccer.

Home lawn owners derive the benefits of both physical exercise and therapeutic relaxation from the stresses of the work place through activities involved in the care and grooming of lawns. Many people find lawn maintenance an excellent opportunity to enjoy reasonable exercise and a healthy mental diversion.

-

-

-

Bibliography

Aldous,D.,E. and Chivers, I .H. (2002) *Sports Turf and Amenity Grasses: A Manual for Field Use and Identification*. LandLinks Press , Collingwood 120p [A comprehensive and easy to follow manual from Australia]

Beard J.B. (1973) *Turfgrass: Science and Culture* Englewood Cliffs, N.J.: Prentice -Hall.[A classic work, pioneering work that has been a guides for north American turf managers for decades]

Beard, J.E. and Green, R.L. (1994). The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans. *Journal of Environmental Quality* 23(3): 452-460 [Explains the hazards to the environment and to human health of agro-chemicals including fertilizers that are used in turf establishment and management]

Bell, G.E. (2011). Turfgrass physiology and ecology: advanced management principles *2011 Turfgrass physiology and ecology: advanced management principles. CABI, Wallingford, UK and Cambridge, MA, USA* [A more technical text for advanced students that focuses on the processes within the plant and its significance for major challenges like drought and cold]

Busey, P. (1989). Progress and benefits to humanity from breeding warm-season grasses for turf. p. 49-70 in: D. A. Sleper, K. H. Asay, and J. F. Pedersen (eds.). *Contributions from breeding forage and turf grasses*. CSSA Spec. Publ. 15, Crop Science Society of America, Madison, Wisconsin, USA. [Part of a major work on turf grass breeding with many helpful suggestions about selection criteria and hybridization]

Busey P. and Myers, B.J., (1979). Growth rates of turfgrass propagated vegetatively. *Agron. J*. 71:817-821. [Deals with the practicality of vegetative propagation has some useful formulae for calculating the number of setts required to cover a given areas of turf for different purposes]

Hanson, A. A. (1972a). Breeding of grasses. p. 36-52. In V. B. Youngner and C. M. McKell (eds.) *The biology and utilization of grasses*. Academic Press, New York. [A general account of principles and practices in grass breeding programs]

Hejduk, S. (2012), Turfgrass physiology and ecology: advanced management principles. *Grass and Forage Science*, 67: 151.doi: 10.1111/j.1365-2494.2011.00849.x [For advanced students a new up to date text on plant physiology]

Pessarakli, M. (Ed) 2008 *Handbook of Turfgrass Management and Physiology* CRC Press, NY p.690 (A comprehensive and useful manual fort students and managers of sports fields, golf courses etc where turf management is so vital]

Tracy, S. M. (1917). *Bermuda grass*. United States Dept. of Agric. Farmers' Bull. 814., USDA, Washington, DC. [An early account of the importation and evaluation of Bermuda grass in USA]

Wang, Z.Y. and Ge, Y.X. (2006) Recent Advances in Genetic Transformation of Forage and Turf Grasses *In Vitro Cellular & Developmental Biology. Plant* 42 (1) pp. 1-18 [A specialist approach outlining techniques for tissue culture and other advanced techniques including a molecular biology approach to turf grass breeding]

Biographical Sketches

Dr. Huiling Ma is a Professor in the College of Grassland Science, of Gansu Agricultural University in China. She received her BSc (Biology) and MSc (Plant Physiology) from Beijing Normal University in China, and a PhD (Grassland Science) at Gansu Agricultural University in China. Her research focuses on breeding of forage and turfgrass by biotechnology. She has worked at Forestry College of Beijing Forestry University, in China as a postdoc. She has also worked at Department of Environmental Biology, University of Guelph, in Canada as a visiting scientist to do the research on induction of disease resistance in turfgrass.

Dr. Yuzhu Li is a Lecturer with the College of Grassland Science, Gansu Agricultural University (GAU), in China. She received a BSc (Grassland science) from University of GAU, MSc (Protection and Utilization of Wild Animal and Plant) and a PhD (Grassland science) from GAU. Her research focuses on Germplasm resources and breeding of Forage and Turfgrass. As a teacher, her main teaching work is to give the course on turfgrass Establishment and Management for undergraduates.

Dr Victor Squires is an Australian who as a young man studied Botany/Ecology. He has a PhD in Rangeland Science from Utah State University**.** USA. He is a former Dean of the Faculty of Natural Resources at the University of Adelaide and was the Foundation Director of the National Key Center for Dryland Agriculture and Land Use Systems, Australia. Since retirement from the University, Dr Squires was a Visiting Fellow at the East West Center in Hawaii and is currently an Adjunct Professor in the University of Arizona, Tucson. USA and at Gansu Agricultural University, Lanzhou, China. He has been a consultant to World Bank, various UN agencies and the Asian Development Bank. He was GEF Advisor on a World Bank pastoral development project in NW China in 2006-2007. He is author of over 100 papers in refereed journals and numerous invited chapters and author/editor of 6 books. He was awarded the 2008 International Award and Gold Medal for International Science and Technology Cooperation by the Government of China and in 2011 was the recipient of a Friendship Award from the government of China (the highest honor awarded to foreigners).