Biological insecticides need to be handled and applied with care in order to be effective. Since control is a result of the activities of living organisms, the source of the product and how it is shipped affect the viability of the organisms (48). In addition, soil conditions at the time of application must be favorable to the growth of the organisms. For example, entomopathogenic or insect-eating nematodes survive best in moist, loamy soils that have soil temperatures between 65° and 85° F. Since they are able to withstand high pressure, you can apply these biological control organisms using a sprayer or irrigation equipment (49). The ATTRA publication *Biointensive Integrated Pest Management* provides detailed information on biological control practices. It also contains extensive lists of suppliers for biopesticides and microbial pest control agents.

Table 4 (see Appendix) summarizes cultural and biological control measures for common turf insect pests.

Turf weeds. Weeds are plants growing in the wrong place. The type of lawn you are interested in having will define which plants are weeds. For example, for someone developing a natural lawn, white clover is an integral component of the turf. For people wanting a pure grass lawn, white clover is a weed. Using good turf management practices that favor the growth of desired species allows these plants to out-compete undesired species. Essential management practices for weed control include (22):

- Growing grass species appropriate for your region and your soil conditions
- Eliminating soil compaction
- Reducing wear on the lawn or turf
- Providing turf soil with appropriate and balanced levels of fertilization
- Overseeding with cool-season grasses to maintain grass growth in the fall and spring
- Watering turf deeply and infrequently during dry periods
- Ensuring proper drainage
- Increasing mowing height

Table 5 (see Appendix), which summarizes soil, weather, and management conditions that favor the growth of weeds. To reduce stress on turf and decrease infestations from weeds, make management changes to alter these weed enhancing conditions.

Mowing to control weeds. Raising the mower height reduces the incidence of some common turf weeds. Research conducted at the University of Maryland showed that mowing turf at 3 inches, especially during the spring, provided as much control of crabgrass as did the use of herbicides (50). The higher cut reduced the stress on the turfgrass and they were able to choke out the crabgrass.

Mowing at a lower cut during seed set can help control annual bluegrass, crabgrass, goosegrass, foxtail, barnyardgrass, fall panicum, and dallisgrass. This technique must be carefully timed to coincide with early seed set. Attach a clippings bag to the mower to collect and remove seed heads. Also be careful not to mow so low that you stress the desired turf species (4).

When not mowing to collect and remove seed heads, leave the grass clippings on the soil to control weed growth. Clippings from a variety of different turf species contain allelopathic compounds that suppress the germination and growth of certain weeds (4, 47). Many tur grass roots also produce allelochemicals that suppress the growth of weed seeds. Raising the mowing height favors root growth and the production of these allelochemicals.

Corn gluten meal is effective in the pre-emergence control of various weed species, including crab grass, foxtail, pigweed and dandelion. This animal feed product controls weed growth by inhibiting root formation (51). Studies demonstrate that repeated applications increase the effectiveness of this natural herbicide. These studies show that corn gluten meal initially reduced weeds by 60 percent, by 80 percent the second year, and by 90 percent in the third year. The main drawback to using corn gluten meal is its high cost, which makes its use economically feasible only in small areas. The average cost is $1.50/lb., with recommended applications rates of 40 to 65 pounds per 1,000 square feet (52). Since it contains 10% nitrogen, it should be managed as both a fertilizer and a herbicide. University of Iowa turfgrass researcher, Nick Christians has compiled a list of suppliers of corn gluten meal,

which is available at: <http://www.public.iastate.edu/~isurf/tech/cgmwebsite.html>.

Vinegar has recently gained attention as an effective natural post-emergence herbicide. It works by degrading the waxy cuticle layer on weed leaves, resulting in desiccation. More frequent applications or applications with a stronger solution are needed to control weeds with very thick cuticle layers. While vinegar typically contains approximately 5% acetic acid, distillation can increase this concentration to 15%, and freeze evaporation can increase it to 30%. Research conducted by the USDA Agricultural Research Service demonstrated that vinegar at 10, 15, or 20% acetic acid concentrations killed 80 to 100% of giant foxtail, common lambsquarters, smooth pigweed, and velvetleaf (53). Some gardeners have seen increased effectiveness by adding lemon juice to the vinegar and applying it during the heat of the day (53).

Like corn gluten meal, vinegar is an expensive treatment for large areas. Approximate costs for broadcast application of vinegar are $66.00 per acre for 20% acetic acid and $99.00 per acre for 30% acetic acid (53).

While vinegar readily degrades in the soil and has no long-term impact on soil organisms (soil pH decreases at the time of application but returns to its original level in less than two days), it is caustic. When applying this material, you should wear a mask to avoid inhalation and gloves to prevent skin contact (55).

Summary

A lawn that is healthy requires less irrigation and resists pests and diseases. Establishing and maintaining a healthy lawn means reducing or eliminating conditions that put stress on the turf. A soft, microbially-rich soil allows for rapid water infiltration, good water and nutrient holding capacity, unimpeded root growth, efficient nutrient mineralization, and effective antagonistic control of pests and diseases. Regular additions of mature compost enhance soil quality while providing biological control of diseases and certain weeds. Raising mowing height to 2 ½ to 3 inches, keeping mower blades sharp, and returning mower clipping to the soil stimulates healthy turf growth and reduces the potential for diseases. Similarly, watering infrequently—but to the depth of root penetration—minimizes both turf stress and the environmental conditions that favor root diseases. A diversity of species within a lawn reduces insect and weed infestations. Natural lawns including clover, wildflowers, or groundcovers that are drought or shade tolerant add variety to a landscape while reducing maintenance time and expenses.

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Organizations

Golf Course Superintendents Assoc. of America
1421 Research Park Dr.
Lawrence, KS 66049-3859
Telephone: 800-472-7878, 785-841-2240
http://www.gcsaa.org

The Golf Course Superintendents Association of America (GCSAA) supports research on environmentally sensitive turfgrass care. Their magazine, Golf Course Management, includes articles on least toxic pesticide use and practices, integrated pest management (IPM), biological control, wildlife and golf courses, water saving practices, and compost use in golf course management, among other topics.

Turfgrass Resource Center / Turfgrass Producers International
1855-A Hicks Rd.
Rolling Meadows, IL 60008
Telephone: 800-405-8873, 847-705-9898.
FAX: 847-705-8347
E-mail: info@TurfGrassSod.org
Web page: http://www.TurfgrassSod.org

A member's Web page with information about turfgrass varieties, turf soil management, and lawn watering practices. Also includes a database of turfgrass specialists.

National Turfgrass Evaluation Program
Kevin Morris, Executive Director
National Turfgrass Evaluation Program
10300 Baltimore Ave. Bldg. 003, Rm. 218
Beltsville Agricultural Research Center-West
Beltsville, MD 20705
Telephone: 301-504-5125
E-mail: kmorris@ntep.org
Web page: http://www.ntep.org/contact.htm

The National Turfgrass Evaluation Program (NTEP) is one of the most widely-known turfgrass research programs in the world. NTEP currently evaluates seventeen turfgrass species in as many as forty U.S. states and six provinces in Canada. Their Web page provides annual evaluation results on turfgrass quality, color, density, resistance to diseases and insects, tolerance to heat, cold, drought, and traffic.

United States Golf Association Green Section
P.O. Box 708
Far Hills, NJ 07931
Telephone: 908-234-2300
USGA Publications: 1-800-336-4446
Web page: http://www.usga.org/green/index.html

Golf course maintenance publications cover turf management, IPM for golf courses, landscape restoration, environmental issues for golf course management and construction, irrigation systems, waste water reuse, and bird conservation on golf courses.

NOFA Accredited Organic Land Care Professionals
c/o NOFA Connecticut
PO Box 386
Northford, CT 06472-0386
Web page: http://www.organiclandcare.net/professionals.php

They wrote the Standards for Organic Land Care. Their Web page also lists names of lawncare professionals in the Northeast who are NOFA Accredited Organic Land Care Professionals.

Resources

Books

Least-toxic and Organic Lawn Care

Standards for Organic Land Care: Practices for Design and Maintenance of Ecological Landscapes.
Organic Land Care Committee. 2001. 66 p.
Northeast Organic Farming Association of Connecticut
PO Box 3
Northford, CT 06472-0386.
Web page: <http://www.nofaic.org/store/ct/index.php>

This manual describes how to grow an organic lawn following an ecological stewardship philosophy for designing and maintaining landscapes. Written by landscape professionals, scientists, and citizen activists. It includes lists of preferred, allowed, and prohibited materials and practices for organic land care. Purchase of this manual includes the booklet A Citizen's Guide to Organic Land Care, which answers, in customer-friendly terms, the questions: what is an organic lawn? and what are the advantages of an organic lawn?

Organic Lawn Care
Bruneau, A.H., Fred Yelverton, L.T. Lucas, and Rick L. Brandenburg. 1997. Publication AG-562. North Carolina Cooperative Extension Service. 32 p.
Department of Agricultural Communications
North Carolina State University
Box 7603
Raleigh, NC 27695-7603

Practical information for homeowners. Maintenance schedules, sources of organic fertilizers, organic control strategies for insects and diseases, and recommended cultivars and planting dates for North Carolina.

Handbook of $uccessful Ecological Lawn Care
Sachs, Paul D. 1996. 290 p.
Edaphic Press
PO Box 107
Newbury, VT 05051
Telephone: 802-222-4277

Well-researched handbook, written for professionals who install and maintain lawns. The

book is divided into two sections. The first, called In the Field, includes chapters on turfgrass dynamics, installing a new lawn, cultural practices, turfgrass pests, and soil testing and fertility. Part Two focuses on the business aspects of running a lawn care business. This book is comprehensive in its approach to the soil-turf complex.

Ecological Golf Course Management
Sachs, Paul D., and Richard T. Luff. 2002. 197 p.
Wiley Publishers
Web page: <http://www.wiley.com/cda/sec/0,,10734,00.html>.

A comprehensive publication on ecological turf management. It focuses on managing the health and welfare of all soil organisms from a single-celled bacterium to fully developed turf plants. It also points out ways to exploit natural plant defense systems that have been largely ignored and to engage many of the powerful allies that live above and below ground.

Down-to-Earth Natural Lawn Care
Raymond, Dick. 1993. 176 p.
Storey Communications
25 Main St.
Williamstown, MA 01267
Telephone: 800-793-9396

Natural lawn care for residents or landscape professionals.

<u>Pest and Disease Control</u>

Turfgrass Problems: Picture Clues and Management Options
Eva Gussack and Frank S. Rossi. 2001. 214 p.
Natural Resource, Agriculture, and Engineering Service (NRAES)
Cooperative Extension
152 Riley-Robb Hall
Ithaca, New York 14853-5701
Telephone: 607-255-7654
Fax: 607-254-8770
E-mail: nraes@cornell.edu.
Web page: <http://www.nraes.org/publications/nraes125.html>

A compact, spiral-bound guide with over 130 color photos designed to help readers identify turfgrass problems and implement appropriate management strategies. The guide covers problems of cool-season turfgrasses caused by non-living (abiotic) or living (biotic) factors. Each problem discussion includes photos, a detailed description, conditions under which the problem tends to occur, and non-chemical management strategies. Also includes chapters on scouting and sampling procedures and symptom timelines for when in the season problems are likely to occur.

IPM Handbook for Golf Courses
Schumann, G., P. Vittum, M. Elliott, and P. Cobb. 1998. 264 p.
Wiley Publishers
Web page: <http://www.wiley.com/cda/sec/0,,10734,00.html>

An excellent introductory handbook for golf course superintendents. Describes IPM and how it can be performed on golf courses. Chapters include site assessment, scouting and monitoring, cultural control strategies, biological and chemical control strategies.

Biological Control of Turfgrass Diseases
Cornell Media Services Resource Center. 12 p.
Ithaca, NY 14853
Telephone: 607-255-2080
Web page: http://www.cce.cornell.edu/publications/gardening.cfm

Lists biological controls for turfgrass diseases and describe the use of organic fertilizers, suppressive composts, and microbial fungicides.

IPM for Lawns.
Bio-Integral Resource Center. 1987. 70 p.
PO Box 7414
Berkeley, CA 94707
Telephone: 510-524-2567
Web page: <http://www.birc.org/>

Bio-Integral Resource Center (BIRC) specializes in finding non-toxic and least-toxic, integrated pest management (IPM) solutions to urban and agricultural pest problems.

The Chemical-Free Lawn
Schultz, Warren. 1989. 208 p.
Rodale Press
33 E. Minor St.
Emmaus, PA 18098
Telephone: 800-527-8200

Designed for homeowners. Includes information on assessing lawn problems, species and cultivars, seeding, sodding, sprigging, fertilizing, mowing, watering, and fighting weeds, insects, and diseases without chemicals.

Compendium of Turfgrass Diseases. 2nd ed.
Smiley, Richard W. et al. 1992. 102 p.
American Phytopathological Society
3340 Pilot Knob Rd.
St. Paul, MN 55121-2097
Telephone: 612-454-7250

Management of Turfgrass Diseases. 2nd ed.
Vargas, M.J., Jr. 1993. 320 p.
Lewis Publishers
2000 Corporate Blvd. NW
Boca Raton, FL 33431
Telephone: 800-272-7737

Managing Turfgrass Pests
Watschke, Thomas L., Peter H. Dernoeden, and David Shetlar. 1994. 384 p.
Lewis Publishers
2000 Corporate Blvd. NW
Boca Raton, FL 33431
Telephone: 800-272-7737

Alternative Lawns

Easy Lawns: Low-Maintenance Native Grasses for Gardeners Everywhere
Stevie Daniels (ed.). 1999. 111 p.
Brooklyn Botanic Garden
1000 Washington Ave.
Brooklyn, NY 11225
Telephone: 718-622-4433
Web page: <http://www.bbg.org/gar2/topics/sustainable/handbooks/lawns/>

This book is a compilation of information on the establishment of no-mow and native grass prairie lawns. Each chapter focuses on low-maintenance lawn species and management practices for different regions of the country.

The Wild Lawn Handbook: Alternatives to the Traditional Front Lawn.
Daniels, Stevie. 1995. 256 p.
Macmillan
New York, NY

A practical guide for transforming grass lawns into beautiful alternative lawns using native grasses, ferns, mosses, wildflowers, low-growing shrubs, and perennials. Includes detailed instructions on choosing, installing and maintaining a wild lawn, including a chapter on landscaping ordinances.

Gardening with Prairie Plants: How to Create Beautiful Native Landscapes
Wasowski, Sally. 2002. 285 p.
University of Minnesota Press
Minneapolis, MN

A beautifully illustrated guide to establishing prairie landscapes. Describes methods for designing, installing, and maintaining yards with prairie plants. Provides extensive and detailed profiles of prairie flowers and grasses and how to use them in prairie lawns.

Electronic database

Turfgrass Information Center
Michigan State University
100 Library
East Lansing, MI 48824-1048
Telephone: 517-353-7209
E-mail: tgif@pilot.msu.edu
Web page: <http://www.lib.msu.edu/tgif/>.

The Turfgrass Information Center (TIC) at Michigan State contains the most comprehensive collection of turfgrass educational materials publicly available in the world. The TIC maintains the Turfgrass Information File (TGIF), an on-line computer based bibliographic database of turfgrass research data. Subscriptions or flat rates available. See their Web site for more information.

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By Barbara Bellows
NCAT Agriculture Specialist

Edited by Paul Williams and David Zodrow
Formatted by Cynthia Arnold

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HTML
http://www.attra.ncat.org/attra-pub/turfcare.html
PDF
http://www.attra.ncat.org/attra-pub/PDF/turfcare.pdf

IP123

APPENDIX: Table 1. Characteristics of good quality compost for turf

Compost Characteristic	Analysis
Appearance	few recognizable components of original material remain. Structure is light and crumbly.
Color	dark brown to black (but not dark black, which indicates overheating during the composting process)
Texture or particle size	fine texture, particles smaller than 1/2 inch for incorporation, smaller than 1/8 for topdressing
Odor	earthy aroma, no smell of ammonia or sulfur
Temperature	not warm to the touch
Moisture content	30 to 50%
Carbon to nitrogen ratio (C:N ratio)	15:1 to 20:1
Organic matter	more than 25%
Humus	color chromotography test between 50 and 80 for finished compost
Ammonium	0.2 to 3.0 ppm
Nitrate	< 300 ppm
Sulfides	zero to trace
pH	6.5 to 8.5; pH 7 optimal
Heavy metals	lower than allowable limits
Soluble salts	conductivity less than 3 millimhos
Microbial profile	•10,000 to 20,000 species of bacteria per gram •aerobic bacteria populations should be between 100 million to 10 billion CFU/gdw •aerobic bacteria should outnumber anaerobic bacteria by ratio of 10:1 or more •Pseudomanas bacteria populations should be between 1 thousand to 1 million CFU*/gdw •nitrogen-fixing bacteria populations should be between 1 thousand to 1 million CFU/gdw •yeasts and fungi populations should be between 1 to 10 thousand CFU/gdw •actinomycete populations should be between 1 to 100 million CFU/gdw
* CFU/gdw is colony forming units per gram dry weight	
Sources: 4, 5, 6, 40	

APPENDIX: Table 2. Organic Nutrient Sources

	Nitrogen Sources	Phosphorus Sources	Potassium Sources
Preferred	• alfalfa meal • compost • compost tea	• compost • compost tea • green manures	• alfalfa meal • compost • compost tea
Allowed	• vegetable meal such as soybean meal, corn gluten meal, cotton seed meal, and peanut meal • blood meal from U.S. sources • fish emulsion or meal	• greensand • rock phosphate • steamed bone meal from U.S. sources	• greensand • seaweed • Sul-Po-Mag • potassium sufate
Prohibited	• leather meal • Chilean nitrate • synthetic nitrogen fertilizers	• synthetic phosphorus fertilizers	• muriate of potash • synthetic potassium fertilizers
	Do not use: • uncomposted manure, since it contains weed seeds and pathogens • sewage sludge, since it may contain heavy metals and pathogens		

Source: 6

APPEINDIX: Table 3. Characteristics of Common Turf Grasses

Lawn Grass	Heat or Cold Tolerance	Shade	Drought	Durability or Wear	Pest Resistance	Soil Preference	Maintenance Level	Establishment Method
Warm-Season Grasses								
Bahiagrass	Heat tolerent	Moderate - Poor	Good - Excellent	Poor - Good	Nematodes- V. Good Diseases - Good	Acid, sandy	Low - Moderate	Seed, sod
Bermudagrass	Heat tolerent	Poor- Very Poor	Good- Excellent	Good - Excellent	Nematodes- Poor Diseases - Good	Wide range	Medium - High	Sod, sprigs, plugs, seed
Carpetgrass	Heat tolerent	Fair -Moderate	Poor	Poor	Nematodes-Poor Diseases - Moderate	Acid, wet	Low	Seed, sprigs
Centipedegrass	Heat tolerent	Fair-Good	Good	Poor	Nematodes-Poor Diseases - Good	Acid, infertile	Low	Seed, sod, sprigs, plugs
St. Augustinegrass	Heat tolerent	Good- Very Good	Good - Poor	Poor - Good	Nematodes-Good Diseases-Moderate	Wide range	Medium	Sod, plugs, sprigs
Zoysiagrass	Heat tolerent	Good	Good- Excellent	Good - Excellent	Nematodes-Poor Diseases - Good	Wide range	High	Sod, plugs
Cool-Season Grasses								
Kentucky Bluegrass	Heat - moderate Cold - moderate	Good	Good	Good	Diseases- moderate	Wide range	Moderate -High	Seed, sod
Rough-stalk Bluegrass	Heat - moderate Cold - moderate	Moderate	Poor	Poor	Diseases- moderate		Moderate	Seed, sod
Tall Fesue	Heat - moderate Cold - moderate	Good - Very Good	Very Good	Good - Very Good	Diseases- moderate	Wide range	Low - Moderate	Seed, sod, plugs
Red Fescue	Northern		Good- Very Good		Resistant to red thread	Acid soils	Low	Sod, plugs, sprigs
Annual Ryegrass	Heat- poor Cold - moderate	Poor	Poor	Good	Diseases- moderate		High	Seed
Perennial Ryegrass	Heat - moderate Cold - moderate	Good- Very Good	Good - Poor	Good	Allstar - high insect resistance		Low- Moderate	Seed, sod
Native Grasses								
Buffalograss	Heat-good Cold - moderate	Good	Very Good	Moderate	Disease-good		Low	Seed, sod, plugs
Blue Gamma	Heat-moderate Cold -good	Good	Good	Moderate	Disease-good		Low	Seed, sod
Crested Wheat grass	Heat-moderate							Seed, sod

Sources: 56, 57, 58

APPENDIX: Table 4. Cultural Practices for Turf Disease Control

Disease	Grass species affected	Resistant varieties	Aeration	Mowing	Fertility	Watering / Leaf wetness	Other
Anthracnose			increase aeration	• increase mowing height	increase	• reduce leaf wetness	
Brown patch	• Fescue • Ryegrass • Bluegrass • Bermudagrass • St. Augustinegrass		increase aeration		• reduce N in late spring, summer • adjust pH to 6 - 6.5	• water deeply, infrequently • water early in day • reduce leaf wetness • provide good drainage	• topdress compost
Dollar spot	• Bluegrass • Ryegrass • Centipedegrass • Bermudagrass • Zoysiagrass	available	increase aeration	• collect and compost clippings	• adequate fertilization necessary • raise pH	• water deeply, infrequently • avoid drought stress • water early in day • reduce leaf wetness	• prevelent in dry weather • topdress compost
Fairy ring	All cool and warm season grasses		increase aeration		increase N, iron		• remove excess organic matter • decrease thatch • rototill or remove soil
Fusarium				• increase mowing height	reduce N	• avoid drought • reduce leaf wetness	• reduce thatch • prevelent in cool weather
Leaf spot	• All cool-season grasses • Bermudagrass	available		• increase mowing height especially in late spring and summer • keep mower blades sharp	reduce N	• water deeply, infrequently • water early in day • reduce leaf wetness	• reduce thatch
Necrotic ring spot		available	increase aeration		minimize stress	• minimize stress	• reduce thatch • topdress compost
Powdery mildew	• Bluegrass	shade-tolerant cultivars	increase aeration	increase mowing height	reduce N	• water deeply, infrequently • water early in day • reduce leaf wetness	• reduce shade • prevelent in cool weather
Pythium blight				do not mow when wet	reduce N	• do not water at night • improve drainage	• reduce shade • topdress compost
Pythium root rot			increase aeration	increase mowing height		• improve drainage	• reduce shade • heavy fall compost application

APPENDIX: Table 4. Cultural Practices for Turf Disease Control - Continued

Disease	Grass species affected	Resistant varieties	Aeration	Mowing	Fertility	Watering / Leaf wetness	Other
Red thread/pink patch	All cool-season grasses	available		collect and compost leaf clippings	increase fertility, pH	• water deeply, infrequently • reduce leaf wetness	• improve air movement • prevelent in cool weather • prevelent in dry weather • topdress compost
Rust	• Fescue • Ryegrass • Bluegrass • Zoysiagrass	available		collect and compost leaf clippings	increase	• minimize stress • maintain good soil moisture • reduce leaf wetness	• reduce shade • prevelent in dry weather
Slime molds	All cool and warm season grasses			collect and compost leaf clippings			• remove mold by brushing or washing turf • reduce thatch • prevelent in cool weather
Southern Blight	• Bluegrass • Ryegrass				fertilize properly	• water deeply, infrequently • reduce leaf wetness	• reduce thatch
Summer patch				increase mowing height	lower pH		
Stipe smut		smut-free seed			reduce N	minimize stress	
Take-all patch	• St. Augustinegrass			increase mowing height	lower pH increase P, K decrease Ca	improve drainage	
Yellow patch					reduce N	• reduce leaf wetness	reduce shade
Yellow tuft					reduce N increase iron	• reduce leaf wetness • improve drainage	

Sources: 12, 13, 22

APPENDIX: Table 5. Cultural and Biological Control Methods for Turf Insect Pests and Other Athropods

Insect Pest	Geographical Locations Affected	Endophytes	Cultural control methods	Botanical Pesticides	Biological Insecticides
Root feeders					
White grubs	• Northeast • Southeast • Midwest • Plains states • Northwest • Southwest	available for cool-season grasses	• withold water in July and early August when eggs need water to hatch • increasing mowing height to 3 inches enhances milky spore effectiveness	• Neem	• Bacillus popilliae (Milky spore) to control Japanese Beetles • Beauveria bassiana • Bacillus japonensis • Entomopathogenic nematodes
Mole crickets	• Southeast • Gulf states				• Bacillus popilliae • Entomopathogenic nematodes • Beauveria bassiana
Stem feeders					
Billbugs	• Southeast • Plains states	available for cool-season grasses	• remove thatch to reduce habitat • reduce compaction • water deeply in spring	• Neem • Diatomaceous earth for adults	• Entomopathogenic nematodes • Beauveria bassiana
Juice suckers					
Chinch bugs	• Northeast • Southeast • Gulf states • Southwest	available for cool-season grasses	• resistant varieties of grass • water regularly, especially early in season	• Neem • Insecticidal soap	• Beauveria bassiana
Mites			• frequent light watering	• Insecticidal soap	
Spittlebugs	• Zone 8		• water thoroughly to remove bugs • water lightly during heat of the day		
Leaf eaters					
Sod webworms	• Northeast • Southeast • Gulf states • Midwest • Plains states • Northwest	available for cool-season grasses	• mow to 3 inches • remove thatch to reduce habitat • ensure good drainage • avoid drought conditions	• Neem • Insecticidal soap	• Entomopathogenic nematodes • Bacillus thuringiensis
Crane flies	• Northwest		• enhance fertility • aerate lawn		

APPENDIX: Table 5. Cultural and Biological Control Methods for Turf Insect Pests and Other Athropods - Continued

Insect Pest	Geographical Locations Affected	Endophytes	Cultural control methods	Botanical Pesticides	Biological Insecticides
Cutworms	• Northwest	available for cool-season grasses	• remove thatch to reduce habitat • use pheromone traps to monitor time of egg laying • mow and bag clippings to remove eggs from leaf tips	• Neem • Insecticidal soaps	• Entomopathogenic nematodes • Bacillus thuringiensis
Armyworms	• Southeast • Gulf states	available for cool-season grasses	• remove thatch to reduce habitat	• Neem • Insecticidal soaps	• Entomopathogenic nematodes • Bacillus thuringiensis
Other Arthropods					
Slugs and snails	• Moist, humid climates		• eliminating wet areas in lawn • setting out traps • planting non-preferred plant species	• Copper barriers • Horsetail (Equisetum) extract • Sawdust • Woodash	• Slug-attacking nematodes (available currently only in Britian)
Sources: 6, 13, 58, 59					

APPENDIX: Table 6. Conditions that Favor Weed Infestations						
Weed	**Soil moisture**	**Soil pH**	**Soil Compaction**	**Soil fertility**	**Mowing**	**Shade**
Annual bluegrass	Poor drainage		High	High N	Too low	
Barnyardgrass	Poor drainage					
Birdsfoot Trefoil	Droughty conditions			Low N		
Black Medic	Droughty conditions			Low N		
Broadleaf Plantain		High	High			
Burdock					Infrequent	
Buttercup	Poor drainage					
Chickweed				High N	Too low	
Cinquefoil	Droughty conditions High surface moisture	Low		Low fertility		
Coltsfoot	Poor drainage	Low				
Common Mullein		Low		Low fertility		
Corn Chamomile	Poor drainage	High				
Corn Speedwell			High			
Crabgrass	Droughty conditions			Low N	Too low	
Creeping Bentgrass	Droughty conditions High surface moisture				Too low	
Creeping Speedwell						Too much shade
Creeping Thyme		High				
Curly Dock	Droughty conditions					

APPENDIX: Table 6. Conditions that Favor Weed Infestations - Continued						
Weed	**Soil moisture**	**Soil pH**	**Soil Compaction**	**Soil fertility**	**Mowing**	**Shade**
Dandelion		High			Too low	
English Daisy		Low				
Foxtail				Low fertility		
Goosegrass	Droughty conditions		High			
Hawkweed		Low		Low fertility		
Henbit				Low fertility		
Hop Clover		High				
Lady's Thumb	Poor drainage	Low				
Leafy Spurge	Droughty conditions					
Mallow				Low fertility		
Nutsedge	Poor drainage					
Pigweed	Droughty conditions					
Prostrate Knotweed	Droughty conditions		High			
Prostrate Spurge	Droughty conditions		High			
Red Sorrel		Low				
Speedwell	Droughty conditions			Low N	Too low	
Wild Parsnip				Low fertility		
Yarrow	Droughty conditions					
Yellow Woodsorrel	Droughty conditions					
Sources: 4, 13						

Sustainable Turf Care Executive Summary

Barbara C. Bellows

The key to organic or least-toxic turf management is reducing turf stress. Turf experiences stress from heat, drought, wetness, compaction, nutrient deficiencies or imbalances, and disease and pest infestations. To minimizing stress on turf, you need to pay attention to the following principles:

- Establish and maintain a healthy soil environment
- Include a diversity of species in the lawn environment
- Use cultural practices that reduce stress on turf
- Understand and work with your local soil and climate conditions
- Use biological pest controls

Establish And Maintain A Healthy Soil Environment

A lawn that is healthy requires less irrigation and better resists pests and diseases. Mature compost provides turf plants with a balanced, slow-release source of nutrients. Compost can be tilled into the soil to renovate land for healthy turf growth or applied to existing turf as a topdressing. When topdressing, the best time to apply compost is in the spring or fall. Compost applied in the spring provides nutrients to the soil and turf during the main growing season, while compost applied in the fall helps prolong the growing season, strengthens roots for the dormant season, and promotes early spring growth. Other organic sources of plant nutrients include vegetable and alfalfa meals for nitrogen, rock phosphate and greensand for phosphorus, and alfalfa meal, greensand, and seaweed for potassium.

Besides serving as a complete source of nutrients for turf growth, compost provides food for soil organisms. These organisms help create a soft, porous, well-aerated soil. They also break down thatch and allow for more effective water and nutrient use.

Include A Diversity Of Species In The Lawn Environment

Turf composed of a single species is highly susceptible to becoming weedy and demands more nutrients and water than turf composed of a diversity of species (12). To minimize maintenance problems, use a combination of species appropriate for your location and for the specific conditions within the yard. Also, choose varieties that have resistance to common pests in the area and that do not have a high demand for nitrogen.

Adding legumes such as Dutch white clover, subterranean clover, or black medic can add nitrogen to the soil, increase drought-tolerance, and decrease diseases and weed infestations. When mixed evenly with turf grass species, the resulting lawn has a soft, natural look.

Slow growing or "no mow" lawn mixes provide another option for low-maintenance lawn care. A combination of hard fescue and creeping red fescue is suitable for the cooler, medium-rainfall areas of the upper Midwest and the northeastern United States, and southern Canada. Various sedges and rushes can be used in moister regions.

Wildflowers provide additional color and variety to a yard while also attracting beneficial insects and birds. When purchasing wildflower seeds, select mixtures that are either native to or well adapted to your local climate and soil conditions. Avoid inexpensive seed mixes that contain a high percentage of weedy, aggressive, annual species. Native, warm-season prairie grasses provide an excellent companion to prairie flowers.

Use Cultural Practices That Reduce Stress On Turf

Mowing and watering are normal lawn maintenance practices that can either be used to create a healthy lawn or misused to produce a highly stressed lawn. Raising the mowing height to 2 ½ to 3 inches, keeping mower blades sharp, and returning mower clipping to the soil stimulates

healthy turf growth, controls weeds, and reduces the potential for diseases. Watering infrequently, but to the depth of root penetration, stimulates healthy root growth, minimizes turf stress, and reduces environmental conditions that favor root diseases.

Overseeding allows you to rejuvenate a lawn and fill in bare spots where weeds might otherwise grow (18). Overseeding also allows you to slowly replace inappropriate or disease-prone varieties with more appropriate or more disease-resistant varieties. In mid-latitude areas, it will extend the length of time a lawn remains green into the fall. For lawn rejuvenation, overseeding may be done either in the spring (April or May) or in the fall (September or October).

Other cultural practices that help control turf grass diseases include aerating the soil and turf by raking, coring, or spiking. You can also stimulate the growth of microbial antagonists by applying natural supplements such as lime, ash, compost, liquid seaweed, or fish emulsion.

Biological Pest Control Methods

A light topdressing of high-quality mature compost applied every 30 days can provide effective control of some root pathogens and reduce weed infestation. Compost applications can suppress some soil borne fungal diseases as well as conventional fungicides. You can topdress solid compost or mix with 20 to 30% sand, then incorporated into the soil with an aerator or drag chains. Alternatively, you can apply compost tea—a liquid solution prepared from high quality compost—as a spray.

Various biological pesticides are labeled for turf. The fungus *Trichoderma harzianum* controls several diseases, such as brown patch, dollar spot, pythium root rot, and blight. A commercial mixture of four species of *Bacillus* bacteria provides remedial treatment of turf diseases. *Bacillus popilliae*, also known as milky spore, controls grubs of Japanese beetles and mole crickets. Two species of insect-eating nematodes can be used to control white grubs, billbugs, sod webworms, cutworms, and army worms. These pest predators survive best in moist, loamy soils that have soil temperatures between 65° and 85° F. Since they are able to withstand high pressure, they can be applied using a sprayer or irrigation equipment.

Perennial ryegrass and many types of fescue have a symbiotic relationship with special fungi or endophytes. Grass varieties that contain endophytes produce a bitter toxin that repels most insects and kills many of those that continue to feed. Besides protecting infected grasses from insect pests, endophytes also produce hormone-like substances that increase the growth and vitality of the grass. While endophyte-infected seed must be stored carefully and planted promptly to ensure the survival of the endophyte, once the endophyte-infected grass is planted, the endophyte grows and reproduces with the grass as long as the grass remains viable.

The easiest and most effective method of weed control is to increase species diversity in the lawn. By raising the mower height to 3 inches, especially during the spring, you can obtain the same level of crabgrass control as with herbicides. Leaving grass clipping on the lawn after mowing can control the germination and growth of certain weeds, because the clippings contain allelopathic compounds. Two organically-approved herbicides have demonstrated a high level of control. Corn gluten meal provides pre-emergence control of various weed species, including crab grass, foxtail, pigweed and dandelion. Concentrated vinegar, containing 10 to 20% acetic acid, is an effective post-emergence herbicide that kills giant foxtail, common lambsquarters, smooth pigweed, and velvetleaf. Unfortunately, both of these products are only economical to use in small areas or as a spot-treatment.