2017 Cornell Guide for Commercial Turfgrass Management

Pat Carroll, Superintendent of Cavalry Club (Manlius, NY) conducting pest scouting.
(*Photo by: Jennifer Grant, New York State Integrated Pest Management Program*).

Cornell University
Cooperative Extension

2017 Cornell Pest Management Guidelines for Commercial Turfgrass

Editors in Chief:

Frank S. Rossi (School of Integrative Plant Science - Horticulture, Cornell University, Ithaca, NY), Jennifer A. Grant (NYS IPM Program, Geneva, NY)

Managing Editor:

Carl Schimenti (School of Integrative Plant Science – Horticulture, Cornell University, Ithaca, NY)

Discipline Editors

Pesticide Information: Michael Helms (Pesticide Management Education Program, Cornell University, Ithaca, NY)

Pesticide Application Technology: Andrew J. Landers (Department of Entomology, Cornell University, Geneva, NY)

Turfgrass Culture: Frank S. Rossi (School of Integrative Plant Science - Horticulture, Cornell University, Ithaca, NY)

IPM: Jennifer A. Grant (NYS IPM Program, Geneva, NY); Carl Schimenti (School of Integrative Plant Science - Horticulture, Cornell University, Ithaca, NY)

Plant Growth Regulators: Frank S. Rossi (School of Integrative Plant Science - Horticulture, Cornell University, Ithaca, NY)

Disease Management: Frank S. Rossi (School of Integrative Plant Science - Horticulture, Cornell University, Ithaca, NY)

Insect Management: Kyle Wickings (Department of Entomology, Cornell University, Geneva, NY)

Weed Management: Jenny Kao-Kniffin (School of Integrative Plant Science - Horticulture, Cornell University, Ithaca, NY)

Wildlife Damage Management: Paul D. Curtis (Department of Natural Resources, Cornell University, Ithaca, NY)

Abbreviations and Symbols Used in This Publication

A	acre	F or FLO	flowable	SP	soluble powder
AI	active ingredient	G	granular	ULV	ultra-low volume
D	dust	L	liquid	W	wettable
DF	dry flowable	P	pellets	WDG	water-dispersible granules
DG	dispersible granule	S	soluble	WP	wettable powder
E	emulsion, emulsifiable	SC	soluble concentrate, suspension concentrate	WSB	water soluble bag
EC	emulsifiable concentrate			WSP	water soluble packet

*........ Restricted-use pesticide; may be purchased and used only by certified applicators
† .... Not for use in Nassau and Suffolk Counties
Δ....... Rate and/or other application restrictions apply in New York State. See label for more information

1 Pesticide Information

1.1 Pesticide Classification and Certification

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) created two classifications of pesticides – general-use and restricted-use. **General-use pesticides** may be purchased and used by anyone. **Restricted-use pesticides can** only be purchased by a certified applicator. Restricted-use pesticides must also be used by a certified applicator or someone under their supervision.

The same federal law that classifies pesticides divided applicators into two groups: private and commercial. **Private applicators** use or supervise the use of pesticides to produce agricultural commodities or forest crops on land owned or rented by the private applicator or their employer. A farmer must be certified as a private applicator in order to purchase and use restricted-use pesticides on agricultural commodities. (No certification is needed if a farmer does not use restricted-use pesticides.)

A **commercial applicator** uses or supervises the use of pesticides for any purpose or on any property not covered by the private applicator classification. In New York, a commercial applicator must be certified to purchase or use any pesticide whether it is general- or restricted-use.

More information about pesticide certification and classification is available from your Cornell Cooperative Extension office (cce.cornell.edu/localoffices), regional NYSDEC pesticide specialist (www.dec.ny.gov/about/558.html), the Pesticide Applicator Training Manuals (store.cornell.edu/c-876-manuals.aspx), or the Pesticide Management Education Program (PMEP) at Cornell University (psep.cce.cornell.edu).

1.2 Use Pesticides Safely

Using pesticides imparts a great responsibility on the user to be a good steward of their health and that of others. Keep in mind that there is more to "pesticide use" than the application. Pesticide use includes mixing, loading, transporting, storing, or handling pesticides after the manufacturer's seal is broken; cleaning pesticide application equipment; and preparation of a container for disposal. All of these activities require thoughtful planning and preparation. They are also regulated by state and federal laws and regulations intended to protect the user, the community, and the environment from any adverse effects pesticides may cause.

1.2.1 Plan Ahead

Many safety precautions should be taken *before* you actually begin using pesticides. Too many pesticide applicators are dangerously and needlessly exposed to pesticides while they are preparing to apply them. Most pesticide accidents can be prevented with informed and careful practices. **Always read the label on the pesticide container before you begin to use the pesticide.** Make sure you understand and can follow all directions and precautions on the label. Be prepared to handle an emergency exposure or spill. Know the first aid procedures for the pesticides you use.

1.2.2 Move Pesticides Safely

Carelessness in transporting pesticides can result in broken containers, spills, and contamination of people and the environment. Once pesticides are in your possession, you are responsible for safely transporting them. Accidents can occur even when transporting materials a short distance. You are responsible for a pesticide accident so take every effort to transport pesticides safely. Be prepared for an emergency.

1.2.3 Personal Protective Equipment and Engineering Controls

Personal protective equipment needs depend on the pesticide being handled. **Required personal protective equipment (PPE) are listed on pesticide labels.** These requirements are based on the pesticide's toxicity, route(s) of exposure, and formulation. Label PPE requirements are the minimum that must be worn during the pesticide's use. Pesticide users can always wear more protection than the label requires.

The choice of protective equipment depends on the activity, environment, and handler. The type and duration of the activity, where pesticides are being used, and exposure of the handler influences the equipment you should use. Mixing/loading procedures often require extra precautions. Studies show you are at a greater risk of accidental poisoning when handling pesticide concentrates. Pouring concentrated pesticide from one container to another is the most hazardous activity. More information on personal protective equipment can be found online at umes.edu/NC170/Default.aspx?id= 7184.

Engineering controls are devices that help prevent accidents and reduce a pesticide user's exposure. One example is a closed mixing/loading system that reduces the risk of exposure when dispensing concentrated pesticides. More information on engineering controls can be found online at umes.edu/NC170/Default.aspx?id=7196.

1.2.4 Avoid Drift, Runoff, and Spills

Pesticides that move out of the target area can injure people, damage crops, and harm the environment. Choose weather conditions, pesticides, application equipment, pressure, droplet size, formulations, and adjuvants that minimize drift and runoff hazards. Check the product label for specific application and equipment requirements.

1.2.5 Avoid Equipment Accidents

Properly maintained and carefully used equipment contribute to safe pesticide application. Use the following guidelines to prevent accidents:

- Be sure to turn off your machinery before making any adjustments.
- Do not allow children, pets, or unauthorized people near the pesticide equipment.
- Depressurize tanks or systems between jobs.
- Always return equipment to appropriate areas for cleaning and storage when the application is completed.

1.2.6 Pesticide Storage

Most pesticide applicators use existing buildings or areas within existing buildings to store pesticides. Whether you choose to build a new storage area or use existing buildings, consider several points:

- The site should be where flooding is unlikely.
- It should be downwind and downhill from sensitive areas like houses, ponds, and play areas.
- There should be no chance that runoff or drainage from the site could contaminate surface or groundwater.

Storage facility check list:

- ❑ Is the facility separated from:
    - o Offices, workshops, and livestock areas?
    - o Wells, streams, lakes, ponds, wildlife?
    - o Food and feed?
- ❑ Is the facility made of fire resistant building materials?
- ❑ Does the facility have
    - o Impermeable flooring?
    - o Liquid spill containment (berms to hold 25% of liquid storage)?
- ❑ Can the doors be locked?
- ❑ Is the facility fenced in?
- ❑ Are warning signs posted?
- ❑ Is a spill kit readily available?
- ❑ Are fire extinguishers readily available?
- ❑ Is personal protective equipment readily available?

1.3 Pollinator Protection

Honey bees, wild bees, and other insects are important for proper pollination of many crops. Poor pollination results in small or odd-shaped fruit as well as low yields. Many factors affect pollinator health including lack of seasonal forage, parasites, predators, pathogens, lack of genetic diversity, and pesticide exposure.

To avoid harming bees, remember these general points:

- Before using a pesticide, always read the label for specific pollinator protection requirements;
- Do not spray or allow the pesticide to drift onto blooming crops or weeds;
- Mow blooming weeds before treatment or spray when the blossoms are closed;
- Avoid application during the time of day when bees are most numerous;
- Make applications in the early morning or evening; and
- Avoid making applications over or allowing drift onto hives or apiaries.

Labels on pesticides that are highly toxic to honey bees may carry a statement warning you about hazards to bees and other pollinators. If pesticide sprays that are highly toxic to bees are used in strict accordance with label directions, little to no harm should be done to bees. Note that some pesticides with relatively low toxicity to honey bees can be made more toxic by adding other pesticides. Special care should be taken with tank mixes where pollinator safety may be unknown.

EPA has established bee labeling requirements for nitroguanidine neonicotinoid-containing pesticides (imidacloprid, dinotefuran, clothianidin, thiamethoxam) with outdoor foliar use labeling. These labels have a bee icon and an advisory box with information on routes of exposure and spray drift precautions.

In early 2015 the EPA proposed new pollinator protection label language to protect managed bees under contract pollination services. The intent of this new language is to protect bees from contact exposure to pesticides that are acutely toxic to bees. Once the new language is finalized, the new wording and requirements will be added to pesticide labels.

In 2016, New York State released its pollinator protection plan. This plan discusses the status of pollinators in New York State and how they can be protected. The plan can be viewed online at http://www.dec.ny.gov/docs/administration_ pdf/nyspollinatorplan.pdf.

Additional information on pollinator protection can be found online at www2.epa.gov/pollinator-protection and pesticidestewardship.org/PollinatorProtection/Pages/default.aspx.

1.4 New York State Pesticide Use Restrictions

1.4.1 Restricted-Use Pesticides

In accordance with New York State law, pesticides that are highly toxic or that are persistent and accumulative are classified as restricted-use in New York State. The NYSDEC uses several criteria to classify pesticides as restricted-use including pesticides:

– Having an active ingredient specifically listed in Part 326.2(a) of the pesticide control regulations.

- Having an active ingredient listed in Part 326.2(b) of the pesticide control regulations and used as noted in the regulation.
- That the NYSDEC commissioner feels may need to be restricted in their use to prevent damage to health, property, and/or wildlife.
- That are federally restricted by the EPA.
- Whose label limits use to commercial pesticide applicators.
- Labeled for direct application to or in surface waters.

If a pesticide is classified as restricted-use by the NYSDEC, it may be distributed, sold, purchased, possessed, and used only by a certified applicator or by someone holding a commercial permit or purchase permit. Restricted-use pesticides may also be used by someone under the direct supervision of a certified applicator. ***NOTE:*** NYS regulations require on-site direct supervision when a person under the instruction and control of a certified private applicator uses a *federally* restricted pesticide. Certified commercial pesticide *technicians* are not permitted to purchase restricted-use pesticides.

Federally restricted pesticides will state "RESTRICTED-USE" on the label. Pesticides restricted by the NYSDEC **may not** have label statements indicating they're restricted-use in New York State. Always check the restricted-use status of a pesticide before purchasing or using it to determine any product restrictions or certification requirements.

Restricted-use pesticides mentioned in this publication are preceded by an asterisk (*).

1.4.2 Additional Use Restrictions

The NYSDEC may also determine that a pesticide cannot be used in a particular area of New York State where it poses an unacceptable risk. For example, certain pesticides are prohibited from use on Long Island due to groundwater contamination or other concerns. Pesticides with additional use restrictions will have a label statement or statements indicating areas of the state where the pesticide may not be used.

Pesticide products mentioned in this publication that cannot be used in Nassau and Suffolk Counties are preceded by a dagger (†). Also look for specific notes and comments in this Guideline regarding other use restrictions.

1.5 Verifying Pesticide Registration and Restricted-Use Status

Any pesticide used in New York State must be currently registered with the EPA and the NYSDEC. To verify whether a pesticide is currently registered or classified as restricted-use in New York State, visit the NYSDEC's product registration online database at www.dec.ny.gov/nyspad/products.

1.6 Check Label for Site and Pest

In order for a pesticide to be legally used in New York State, **the site <u>and</u> the pest must be listed on the label in the proper combination.** Other states may not have this requirement.

Before purchasing a pesticide, carefully and thoroughly read the label to be sure that the pest you wish to control is listed for the site (i.e. crop) where you will apply the pesticide. If a pest is not listed for the site you're treating, check the NYSDEC's product registration database to see if a 2(ee) recommendation for unlabeled pest has been approved for the pesticide and the site. (See Section 1.10 for more on 2(ee)s.)

If you are purchasing a pesticide you have used before, be sure to read the label of the newer product prior to purchase. It's not uncommon for sites and/or pests to be removed from a label. Not checking this ahead of time can lead you to make an illegal pesticide application or put you in the position of having an unusable pesticide.

1.7 Pesticide Recordkeeping/Reporting

1.7.1 New York State Requirements

Manufacturers and importers. The NYSDEC requires annual reports from manufacturers and importers documenting all restricted-use product sales within the state. These records include the EPA registration number, container size, and number of containers sold to New York purchasers. Records need to be maintained for at least three years.

Reporting at point of sale. The NYSDEC requires annual reports from every person who sells or offers for sale restricted-use pesticides to private applicators. The reports include each sale to a private applicator of a restricted- or general-use pesticide used in agricultural crop production. Reports include the EPA registration number; product name of pesticide purchased; quantity purchased; date purchased; and location of intended application by address (including 5-digit zip code) or if an address is unavailable, by town or city (including 5-digit zip code). An annual report is required even if no pesticides were sold during the calendar year.

Commercial applicators. The NYSDEC requires **annual reports** from commercial applicators and technicians about their restricted- and general-use pesticide applications. Annual reports include the EPA registration number, product name, quantity of pesticide used, date applied, and location of application by address (including 5-digit zip code). All commercial applicators and technicians must file annual reports even if no pesticide applications were made during the calendar year.

Commercial applicators and technicians must also maintain corresponding **application records** of the dosage rates, methods of application, and target organisms. These records need to be maintained annually, retained for at least three years, and made available for inspection on request by the NYSDEC.

Private applicators. New York State regulations require private applicators to maintain records of the restricted-use pesticides they've purchased and used. These records need to include at a minimum: the restricted-use pesticide(s) purchased; crop treated; application method, and date(s) of application(s). (A form meeting these requirements is available from the DEC online at www.dec.ny.gov/docs/materials_minerals_ pdf/privatercdfrm.pdf. A copy of this form has also been provided at the end of this book.) Records need to be retained for at least three years and must be made available for inspection by the NYSDEC upon request.

More information on New York State reporting and recordkeeping requirements can be found online at www.dec.ny.gov/chemical/27506.html or by contacting the NYSDEC in Albany at 518-402-8748 or PestMgt@dec.ny.gov.

1.7.2 Federal Private Applicator Recordkeeping Requirements

Federal regulations require private applicators to keep records of the *federally restricted-use* pesticides they apply. Federally required records must contain the following:

- Applicator name;
- Applicator certification number;
- Month, day, and year of application;
- EPA registration number for product applied;
- Brand or product name of pesticide applied;
- Crop, commodity, or site treated;
- Size of area treated;
- Total amount of pesticide product applied; and
- Location of the application using any of the following:
  - County, range, township, and section;
  - Maps, GPS coordinates, or written descriptions;
  - A USDA identification system, which involves maps and a numbering system to identify field locations; or
  - The legal property description.

Under federal recordkeeping regulations, spot applications are applications of a restricted-use pesticide to less than 1/10 of an acre on the same day. Spot application records must include: month/day/year of application; brand or product name of pesticide applied; EPA registration number; total amount of pesticide applied; and location of the application designated as a "spot treatment" with a brief description. **NOTE:** Spot treatments do not apply to nurseries or greenhouses. Applications at these locations are recorded as if they are a non-spot application.

Federally required information must be recorded within 14 days of the application and be maintained for 2 years following the application. Access to federal record information is limited to: USDA-authorized representatives presenting identification; state-authorized representatives presenting identification; and attending licensed health care professionals (or those acting under their direction) when treating individuals who may have been exposed to a restricted-use pesticide.

1.8 EPA Worker Protection Standard (WPS) for Agricultural Pesticides

The WPS is designed to reduce the risks of illness or injury resulting from occupational exposures to pesticide handlers and agricultural workers who work in the production of agricultural plants on farms, nurseries, greenhouses, and forests. Generally, WPS requirements include:

- Restricted-entry intervals (REIs) for agricultural pesticides.
- Personal protective equipment (PPE) for handlers and early-entry workers.
- Decontamination supplies and emergency assistance.
- Pesticide safety training and information sharing.
- Specific WPS instructions on pesticide labels.
- Application exclusion zones (new for 2017).

Revised WPS regulations were released in Fall 2015 that affect many of the above items. Most of the revised rule took effect January 2, 2017. A more complete discussion of the WPS and the recent revisions can be found online at https://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps. You can also contact your regional NYSDEC pesticide office for more information.

1.9 Reduced-risk Pesticides, Minimum-risk Pesticides, and Biopesticides

1.9.1 Reduced-risk Pesticides

Since 1993, EPA has expedited the registration of conventional pesticides having low toxicity to humans and nontarget organisms (including fish and birds), low risk of groundwater contamination or runoff, low potential for pesticide resistance, demonstrated efficacy, and compatibility with IPM. EPA refers to materials meeting these criteria as "reduced-risk." The "reduced-risk" designation applies only to certain uses of a particular pesticide and may not include all labeled uses of the product.

1.9.2 Minimum-risk Pesticides

Minimum-risk pesticides are certain pesticides exempt from EPA registration under FIFRA. Since these products are not registered with the EPA, they have no EPA registration number. Minimum-risk pesticides contain only active and inert ingredients outlined in federal regulations (40 CFR 152.25(f)(1) and 40 CFR 152.25(f)(2), respectively). Minimum-risk pesticides must also meet certain label requirements. Detailed information on minimum-risk pesticides is available at: www.epa.gov/minimum-risk-pesticides.

New York State pesticide registration policy exempts minimum-risk pesticide meeting EPA's criteria from product registration requirements. Registration policies may differ in other states.

1.9.3 Biopesticides

EPA defines biopesticides or biological pesticides as certain types of pesticides derived from natural materials such as animals, plants, bacteria, and certain minerals. This group includes microbial pesticides (which contain bacteria, fungi, viruses, etc., as the active ingredient); plant incorporated protectants (pesticidal substances plants produce from added genetic material like corn genetically modified to produce *Bacillus thuringiensis* toxins); and biochemical pesticides comprised of naturally occurring substances that control pests by nontoxic mechanisms (such as pheromones or some insect growth regulators). Biopesticides must be registered with EPA. See www.epa.gov/pesticides/biopesticides/ for more information on biopesticides.

1.10 FIFRA 2(ee) Recommendations

Certain limited variations from the pesticide use directions on pesticide labels are authorized under FIFRA. These "2(ee) recommendations" allow:

1. Use at any dosage, concentration, or frequency less than specified on the labeling unless prohibited by the labeling.
2. Use against a target pest not specified on the labeling unless the label says otherwise.
3. Using any method of application not prohibited by the labeling.
4. Mixtures with fertilizer unless prohibited by the labeling.

In New York State, 2(ee) recommendations must be approved in writing by the NYSDEC. However, pesticides applied for agricultural purposes at less than label rate (unless prohibited by the label) and mixtures with fertilizer (item 4 above) do not require this approval. Requests for a 2(ee) recommendation may only be made by recognized research institutions, certified crop advisers, manufacturers (registrants), or organizations representing individual users. An individual user cannot request approval of 2(ee) recommendations. No fee is required for a 2(ee) recommendation request.
NOTE: Applicators must have the approved 2(ee) recommendation in their possession at the time of application in order for the use to be legal.

1.11 Neighbor Notification

Title 10 of Article 33 of the Environmental Conservation Law requires that before any commercial lawn application is made, the applicator must enter into a written contract with the owner (or owner's agent) of the property to which the application is to be made. Title 10 also requires the posting of visual notification markers. These provisions apply to all commercial lawn applications in New York State. They do not apply to commercial nursery, greenhouse, or other agricultural production operations.

Title 10 also allows counties and New York City to pass a local law and "opt into" additional notification requirements for lawn applications. (Lawn applications include ground, trees, and shrubs). Referred to as the Neighbor Notification Law, these requirements include posting of visual notification markers by homeowners for residential lawn applications, posting of informational signs at retail establishments selling general-use lawn care pesticides and, for certain commercial lawn applications, procedures for 48-hour advance notification to occupants of dwellings, multiple dwellings, and other structures on abutting property with boundaries within 150 feet of an application. Certain pesticides or applications are exempt from this 48-hour prior notification including:

- Directed aerosol sprays from containers 18 fl. oz. or less to protect individuals from an imminent threat from stinging and biting insects.
- Nonvolatile insect or rodent bait in a tamper-resistant container.
- Materials classified by EPA as exempt under 40 CFR 152.25 ("minimum-risk" or 25(b) pesticides).
- Materials classified by EPA as reduced-risk pesticides or biopesticides.
- Horticultural oils and soaps that do not contain synthetic pesticides or synergists.
- Granular pesticides (i.e., solid pesticides applied to ground that are not a dust or powder).
- Pesticides injected into the plant or the ground.
- Spot application of pesticides from a manually pressurized or nonpressurized container of 32 fl. oz. or less to an area of ground less than 9 sq. ft.
- Applications to the ground or turf of any cemetery.
- Emergency application of pesticides to protect human health provided an effort is made to give written notice and notification is also given to the commissioner of health.

NYS pesticide regulation (Section 325.41) describes notifications pesticide applicators conducting commercial or residential lawn applications must do in counties or cities that have opted in to the Neighbor Notification Law. The regulations also discuss placement of signs at stores selling general-use lawn pesticides. Commercial applicators and owners of garden centers should become familiar with the law and regulations found on-line at www.dec.ny.gov/

chemical/8529.html. Contact the local county government to determine if they've opted in to the Neighbor Notification Law.

1.12 Pesticide Use on School and Day Care Center Grounds

New York State Education and Social Service laws restrict the use of pesticides on playing fields, playgrounds, and turf at schools and day care centers. These laws allow only the following pesticide products to be used on these sites:

- Antimicrobials;
- Insecticides used to protect individuals from an imminent threat of a stinging or biting insect packaged in an aerosol can 18 ounces or smaller;
- Non-volatile insect and rodent baits in tamper resistant containers;
- Products containing boric acid or disodium octaborate tetrahydrate;
- Horticultural oils and soaps that do not contain synthetic pesticides or synergists; and
- Pesticides classified as exempt by the US EPA (minimum-risk or 25(b) pesticides).

State law provides for emergency exemptions if it's determined an emergency pesticide application is needed. These exemptions must be approved by the appropriate entity (county health department, NYS Department of Health, NYS Department of Environmental Conservation, or a local school board) as defined in the law.

More information on these restrictions can be found in the final guidance document from the NYSDEC available online at: www.dec.ny.gov/chemical/41822.html.

1.13 Environmental Impact Quotient (EIQ)

There is a wealth of toxicological and environmental impact data for most pesticides that are used in agriculture and horticulture, largely because of the pesticide registration process. However, these data are not all readily available or organized in a manner that is usable to the IPM practitioner. A method called the Environmental Impact Quotient (EIQ) (online at www.nysipm.cornell.edu/publications/eiq/) was devised to determine the environmental impact of most commonly used pesticides (insecticides, fungicides, and herbicides) in agriculture and horticulture. The values obtained from these calculations can be used to compare the environmental impact of different pesticides and pest management programs. The EIQ provides criteria to be used along with the pest manager's knowledge of efficacy, cost and resistance management to select a pesticide product when deemed necessary. The EIQ is based on data obtained from EXTOXNET (extoxnet.orst.edu/), the Cornell Pesticide Management Education Program (pmep.cce.cornell.edu), SELCTV (ipmnet.org/phosure/database/selctv/selctv.htm), the National Pesticide Information Center (npic.orst.edu/ppdmove.htm -developed by the USDA Agricultural Research Service and Soil Conservation Service), Material Safety Data Sheets (MSDS), EPA factsheets and databases, the Pesticide Properties Database (sitem.herts.ac.uk/aeru/projects/ppdb/index.htm), and technical bulletins developed by the agricultural chemical industry.

Factors such as toxicity (dermal, bird, chronic, bee, fish, beneficial arthropod), soil half-life, systemicity, leaching potential, plant surface half-life, surface loss potential, and farm worker, consumer, and ecological effects are all considered when calculating an EIQ for a particular pesticide. The result is a single number describing the EIQ of a pesticide active ingredient. The New York State Food and Life Sciences Bulletin No. 139 entitled "A Method to Measure the Environmental Impact of Pesticides" describes in detail the derivation of the EIQ. The full content of the bulletin is available at the website cited above, along with an updated table of EIQ values, including those for many active ingredients that have come on the market in the nearly two decades since the model was originally developed. Although the model was developed for food crops, the "farm worker" component can be considered equivalent to the effects to turfgrass applicators and the "consumer" component to the turfgrass user, e.g. golfer, athlete, child.

Table 1.13.1. Example of the EIQ Field Use Rating for five fungicides targeting dollar spot.

Material	Active Ingredient	EIQ	% Active Ingredient	Rate	EIQ Field Use Rating
Daconil Ultrex Turf Care	chlorothalonil	37.4	82.5	3.7 oz/1000 ft2 (10.07 lb/acre)	311
*NY 3336F	thiophanate methyl	23.8	41.25	2 fl. oz./1,000 ft2 (5.44 pints/acre)	53.5
Bayleton 50% WSP	triadimefon	27	50	1 oz./1,000 ft2 (2.72 lb/acre)	36.7
Banner Maxx	propiconazole	31.6	14.3	1 oz./1,000 ft2 (2.72 pints/acre)	12.3
Roots EcoGuard Biofungicide	*Bacillus licheniformis*	7.3	0.14	20 fl. oz./1,000 ft2 (54.45 pints/acre)	0.6

Once an EIQ value has been established for the active ingredient of a pesticide, EIQ field use ratings (EIQ-FUR) can be calculated. To compare pesticides and pest management strategies, the dose, the formulation or percent active ingredient of the product, and the frequency of application of each pesticide needs to be considered. The EIQ-FUR was developed to account for different formulations of the same active ingredient and different use patterns. This rating is calculated by multiplying the EIQ value for the specific chemical by the percent active ingredient in the formulation and by the rate used, usually in pints or pounds of formulated product per acre.

EIQ Field Use Rating (EIQ FUR) = EIQ x % Active Ingredient x Rate

The lower the EIQ-FUR, the lower the environmental impact. This method allows comparisons of the environmental impact among pesticides and different pest management programs. Pesticides should be compared based on the EIQ-FUR of the product only, not by the base EIQ of the active ingredient. As an example, if several pesticides are registered against a particular pest, which pesticide has the least impact on the environment? Table 1.13.1 shows a comparison of the environmental impact of five turfgrass fungicides.

In this example, the EIQ Field Use Ratings have been calculated for five fungicides registered for dollar spot control, at the low curative rate. Note that although thiophanate methyl has a lower base EIQ (23.8) than most of the other active ingredients listed, it has the second highest EIQ-FUR. The Field Use Rating is dependent on the %AI and the rate of application. Also be aware that small differences in the EIQ-FUR are not meaningful, rather the relative level and ranking are. The following can be used as a guide for turfgrass managers:

EIQ Field Use Rating

<25	very low
<50	low
50-100	moderate
>100	high
>150	very high

The products listed in this example differ in efficacy, mode of action (coded by FRAC/IRAC/WSSA in table 9), potential for causing resistance, and cost–as well as EIQ-FUR. A turfgrass manager should consider all of these differences when selecting a pesticide and an overall management strategy. The addition of a measure of environmental impact enhances the professional’s ability to make well-informed choices.

The EIQ Field Use Rating can be used to compare different pest management strategies, and to compare seasonal totals from year to year. To do so, calculate the EIQ-FUR for each application made or planned for the season and simply sum them up. By using the EIQ model, it becomes possible for IPM practitioners to easily estimate the environmental impact of different pesticides combinations and choices.

1.13.1 EIQ Calculator

A new tool was recently added to the NYS IPM Program website, the EIQ Calculator. It makes EIQ calculations easy, regardless of the units of weight, volume or area being used. The calculator also references the most current base EIQ values in determining EIQ-FURs. Try it out at https://nysipm.cornell.edu/eiq/calculator-field-use-eiq, and find out the environmental impact of your management on the properties you take care of.

2 Sprayer Technology

2.1 Calibration of Application Equipment

There are only 3 main factors affecting application rate:

- forward speed
- orifice size
- system pressure (for liquid products)

2.1.1 Sprayer Calibration

Sprayer calibration is a two-part exercise and should be conducted during the pre-season check and at regular intervals during the spraying season.

Step 1. Travel Speed Calibration

Travel speed is a critical factor in maintaining accurate application rates and will influence spray deposition. The slower a sprayer travels, the greater the uniformity in spray deposition. Although there is inconsistency in research results that try to determine the effect of travel speed on average spray deposition, all studies to date have been in agreement that the higher the travel speed, the greater the variability in spray deposit. Variation in spray deposit is an important factor where uniformity of spray coverage throughout the canopy is required. Conclusions from research were drawn using travel speeds of 1-4 mph.

Factors that will affect travel speed include:

- weight of sprayer
- slope of terrain
- ground conditions traveled over (wheel slippage!)

The best way to measure travel speed is to operate the sprayer with the tank half filled with water on the same type of terrain as the sprayer will be operated on.

Set up test course at least 100 feet long, measure the course with a tape measure. Do not pace the distance. The longer the course the smaller the margin of error. Run the course in both directions.

Use an accurate stop watch to check the time required to travel the course in each direction. Average the two runs and use the following formula to calculate the speed in MPH.

$$\textbf{Formula} \quad \frac{\text{Ft. traveled}}{\text{Sec. traveled}} \times \frac{60}{88} = \text{MPH}$$

Your figures:

Tractor gear__________ Engine revs. _________

$$\frac{\_\_\_\_\_\_\text{ft.}}{\_\_\_\_\text{sec}} \times \frac{60}{88} = \_\_\_\_\text{MPH}$$

Step 2.A. Record the inputs (for acre basis)	Your figures	Example
Nozzle type on your sprayer (all nozzles must be identical)	__________________	110 04 flat fan
Recommended application volume (from manufacturer's label)	__________________	20 gallons/acre
Measured sprayer speed	__________________	4 mph
Nozzle spacing	__________________	20 inches

Step 2.B. Record the inputs (for 1000 sq. ft. basis)	Your figures	Example
Nozzle type on your sprayer (all nozzles must be identical)	__________________	110 04 flat fan
Recommended application volume (from manufacturer's label)	__________________	1 gallon/1000 sq. ft.
Measured sprayer speed	__________________	4 mph
Nozzle spacing	__________________	20 inches

Step 3.A **Calculate the required nozzle output (acre basis)**	**Example**: GPM = 20 **X** 4 **X** 20 / 5940 = 1600 / 5940 = 0.27 GPM
Formula: GPM = GPA **X** mph **X** nozzle spacing / 5940 (constant)	**Your figures** GPM= ____ **X** ____ **X** ____ / 5940 = ________ / 5940 = GPM
Step 3.B **Calculate the required nozzle output (1000 sq. ft. basis)**	**Example**: GPM = 1 **X** 4 **X** 20 / 136 = 80 / 136 = 0.59 GPM
Formula: GPM = Gal/1000 sq. ft. **X** mph **X** nozzle spacing / 136 (constant)	**Your figures:** GPM = ____ **X** ____ **X** ____ / 136 = ________ / 136 = GPM

Step 4. Operate the sprayer

- Set the correct pressure at the gauge using the pressure regulating valve.
- Collect and measure the output of each nozzle for one minute.
- The output of each nozzle should be the approximately the same as calculated in Step 3 above. Remember 128 fl. oz = one gallon. If output has been calculated at 0.27 GPM then output is 128 multiplied by 0.27 = 34.5 fl. oz. in one minute.
- Consult the nozzle manufacturer's handbook for nozzle flow and pressure.
- Replace all nozzle tips which are more than 5% inaccurate.

2.1.2 Backpack or Hand-Held Sprayer Calibration

Use clean water

Dynamic calibration

1. Select correct nozzle and pressure.
2. Measure an area 10 feet x 10 feet on concrete.
3. Fill sprayer to a known level, mark position.
4. Spray the measured area.
5. Refill sprayer to the mark.
6. Compare quantity collected with nozzle chart and desired amount.

Static calibration

1. Select correct nozzle and pressure.
2. Measure an area 10 feet x 10 feet on concrete, spray and record time taken.
3. Carry out stationary run of same time duration, catching liquid in a graduated measuring jug.
4. Compare quantity collected with nozzle chart and desired amount.

2.2 Decontaminating Turfgrass Sprayers

Sprayers must be thoroughly cleaned inside and out after use. Ideally, a sprayer should be cleaned at the end of each day and especially before switching to a different pesticide. Pesticide residues left on the outside of the sprayer can cause operator contamination. Residues on the inside of the tank or left over pesticides trapped inside the sprayer plumbing system can also contaminate the operator.

Sprayers can also retain tremendous amounts of pesticide solution. Depending on the size and design of the sprayer, there can be nearly 6 gallons of solution left in a sprayer's plumbing. As illustrated in the following table, research conducted on boom sprayers has shown that, depending on the spray tank size, the total chemical solution retained in the sprayer ranged from just under 3 gallons to over 12 gallons. While most turfgrass sprayers are smaller than the examples quoted in the table, operators should be aware that remnants exist and care should be taken. The parts that retained the most chemical solution are the chemical induction bowl, the booms, the tank and the pump and its related piping.

Tests have shown that triple rinsing the spray tank is better than using just one single rinse. For example, using 100 gallons of clean water in one single rinse to clean a 100-gallon sprayer tank reduced the concentration of the original spray solution from 100% to 5% both in the tank and at the nozzle. If triple rinsing was performed using 33 gallons of clean water per rinse, a concentration of 0.2% to 0.5% was gained. The aim is for maximum dilution with minimal use of water. The following table illustrates how triple rinsing reduces the pesticide concentration at the nozzle and the tank drain.

Table 2.2.1. Concentration of pesticide in rinse water.

Rinse Number	Sample Location	Percent Concentration
1	Nozzle	5.5
	Tank Drain	4.8
2	Nozzle	1
	Tank Drain	1
3	Nozzle	0.2
	Tank Drain	0.2

Source: Nilsson, E., Hagenwall H. og Jorgensen L.

Table 2.2.2. Quantity and location of chemical remnants in crop sprayers (in gallons).

	Sprayer Size		
Location	**159 Gallons- 39 foot boom**	**212 Gallons – 39 foot boom**	**396 Gallons – 59 foot boom**
Tank	.50	1.32	4.57
Pump and associated piping	.40	.85	2.22
Pressure agitation	.02	.16	.27
Manifold	.04	.16	.27
Filter relief valve	NA	.15	.23
Chemical induction bowl	1.16	1.69	NA
Total without boom	**2.12**	**4.33**	**7.56**
Booms	.50	2.32	4.76
Total with booms	**2.62**	**6.65**	**12.32**

Adapted from "Quantity and Location of Chemical Remnants within a Range of Field Crop Sprayers by S.E. Cooper. Available: www.hardiinternational.com/Agronomy/Education_Material/pdf/08a.pdf

Before rinsing a sprayer, read the sprayer manufacturer's instructions for specific guidance on the best methods for cleaning your equipment. Also consult the pesticide label for any special cleaning instructions. When cleaning spray equipment, you should use the protective clothing listed on the pesticide label. Sprayer cleaning should be done so that rinse water ***does not*** enter any waterway, field drainage system, or well. Ideally, sprayer rinsate should be applied to a labeled crop. If rinsing needs to be done at the mixing/loading site, it must be done on an impervious surface. All contaminated rinse water must be trapped and either used to mix another load of the same pesticide at the label recommended rates or disposed of at an approved pesticide waste handling facility.

2.2.1 Reducing Cleaning Problems

The need for cleaning can be reduced by good planning and equipment maintenance. The following are suggestions to help reduce cleaning needs:

- Carefully plan how much pesticide to mix so that all mixed pesticides are used up when you are finished with the field.
- Be sure that the sprayer is clean before you use it.
- Make sure all parts of the sprayer are in good condition. Corroded, cavitated or pitted surfaces are prime areas for pesticide residue to hide. Replace any worn parts.
- Mix the chemicals in the correct order. Some chemicals, when mixed in the wrong order, can actually become more difficult to remove from the equipment. Consult the pesticide label for the proper mixing order.
- Follow any label instructions for cleaning spray equipment.
- Be sure that cleaning solutions contact ALL equipment surfaces.
- Remove and clean filters, strainers and nozzle screens separately from the rest of the sprayer.

Table 2.2.3. Commercially available sprayer cleansers.

Product	Supplier	Product	Supplier
Protank Cleaner	Winfield Solutions, LLC P.O. Box 64589 St. Paul, MN 55164-0589 Phone: (855) 494-6343 Web: *http://www.winfieldpro.com/*	**Wipe-Out**	Helena Chemical Company 225 Schilling Blvd. Collierville, TN 38017 Web: www.helenachemical.com
All Clear Tank Decontaminator	UAP Loveland Industries, Inc. PO Box 1289 Greeley, CO 80632 Phone: (970) 356-8920 Fax: (970) 356-8926 Email: webmaster@lovelandindustries.com	**Ag Chem Tank Cleaner**	Ag Chem Equipment Co. Ag-Chem Division 202 Industrial Park Jackson, MN 56143 Phone: (800) 760-8800 Web: www.sprayparts.com

2.2.2 Sprayer Cleansers

Several sprayer cleansers are commercially available. These cleansers should be selected based on the pesticide formulation used. Specific recommendations can be found on the pesticide label, by contacting the pesticide manufacturer or through the label or manufacturer of the cleaning agent you wish to use. Some available cleansers are listed in the table below. Household detergents, such as laundry soaps and household ammonia, can also be used, but they may not adequately deactivate and solubilize the pesticides for effective cleaning. Chlorine bleach solutions should not be used. Cleaning agents can be used to wash both the inside and outside of the sprayer. When using commercial cleansers, follow the product's instructions for the best results.

2.2.3 Tank Rinse Systems (Low-Volume Tank Rinsing)

Tank rinse systems consist of a clean water supply tank mounted to the sprayer and one or more rotating discs or nozzles mounted inside the main sprayer tank. Water is pumped from the clean water tank to the rinse nozzles where the water is sprayed around the inside of the spray tank. These systems are designed for in-field rinsing of the sprayer so that the tank washings can be applied to the field and reduce the amount of time spent traveling.

A tank rinse system can be purchased as an option on some sprayers or as an add-on kit. Rinse systems can also be made from readily available parts and installed on the sprayer. A sample rinse system layout is shown in Figure 2.2.1. A typical rinse system uses 360-degree tank wash nozzles mounted in the top of the tank. These nozzles are available in flow rates of 10 gallons of water per minute at 20 psi up to 20 GPM at 50 psi. If a spray tank has baffles, at least one rinse nozzle per compartment should be provided. In any case, a sufficient number of rinse nozzles should be installed to provide enough rinse water to contact the entire tank interior.

A clean water tank can be plumbed into the sprayer plumbing system to provide the clean rinse water. This tank should be permanently marked "Clean Water Only" so that only clean water is placed in the tank, reducing the chance for contamination of the rinse system. The tank should be mounted above the pump in order to aid in priming the pump. Ideally, the tank should be mounted on the sprayer.

When using tank rinse systems, you may want to check the pesticide label or with the chemical manufacturer to be sure that low-volume rinsing is suitable for the products you're using. Also, during the rinse process, be sure to open and close the pressure valve and other control valves on the sprayer to ensure that any chemical that may be trapped in the valve is rinsed out, further reducing the chance for contamination of future pesticide mixes. To obtain the best results, practice using the rinse system by placing spray marker dye or food coloring in the spray tank. Using the rinse system, run three rinse cycles, making sure the water discharged from the nozzles is completely clear by the end of the third rinse.

2.2.4 Cleaning the Sprayer

The pesticide applicator should try to keep the volume of tank wash water produced to a minimum. Ideally a tank rinse system should be used.

Reminder: Before cleaning application equipment, remember to wear the protective clothing listed on the pesticide label.

1. Be sure that all mixed pesticides have been used up from the sprayer or removed and disposed of properly.
2. Flush sprayer with clean water, making sure to wash all inside surfaces of the tank, including the underside of the lid. Use of a tank rinse system is preferred so that rinsing can be done in the field where the rinse water can be applied to the crop. If a tank rinse system is not available, fill the spray tank about half full with clean water and flush the system for at least 5 minutes using both agitation and spraying. Be sure to open and close any control valves during the rinse process. The rinsate should be applied to the crop at labeled rates. Repeat this procedure two more times.
3. Hose down the outside of the sprayer making sure to reach all parts, scrubbing if necessary.
4. Remove suction, main and in-line filter elements and wash them thoroughly in clean water using a soft bristle brush. Put the filters back on the sprayer when clean.
5. Remove the nozzles, nozzle screens and nozzle bar end caps (if used) and wash them thoroughly in clean water with the appropriate cleanser and rinse. Remember to use a soft bristle brush, such as an old toothbrush, when cleaning nozzle parts.
6. Partly fill the sprayer with clean water and run the sprayer to flush out all parts.
7. Reinstall nozzles and nozzle screens.
8. Hose down the outside of the sprayer once again.

Tank Rinse Nozzle Suppliers
Spraying Systems (TeeJet)
www.teejet.com/techcent/catalog_english/spec_fert.pdf

Delavan
www.delavan.co.uk/zCIP.pdf

References

- Cornell Cooperative Extension. (2002.) **Pest Management Guidelines for Commercial Tree Fruit Production.**
- DuPont Agricultural Products. (1995.) **A Guide to Application Equipment Cleanout for DuPont Sulfonylurea Herbicides.** DuPont Agricultural Products.
- **Hardi International** web site: www.hardi-international.com
- Harrison, Scott and Hock, Winand. (N.D.) Agrichemical Fact Sheet #9 - **Options for In-field Pesticide Sprayer Rinsing and Clean Water Utilization.** Penn State Cooperative Extension. Johnson, Bill, et. al. (1997.) **Cleaning Field Sprayers to Avoid Crop Injury**, Fact Sheet G 4852. MU Extension, University of Missouri - Columbia.
- Peterson, Dallas E., Kuhlman, Dennis K., and Devlin, Daniel L. (1998.) **Cleaning Field Sprayers**. Kansas State University Department of Agronomy.

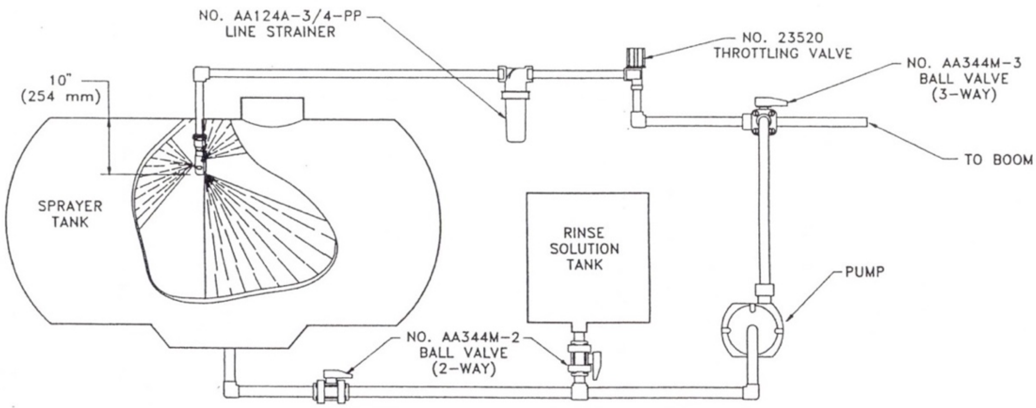

Figure 2.2.1. Sample layout of a sprayer rinse system.

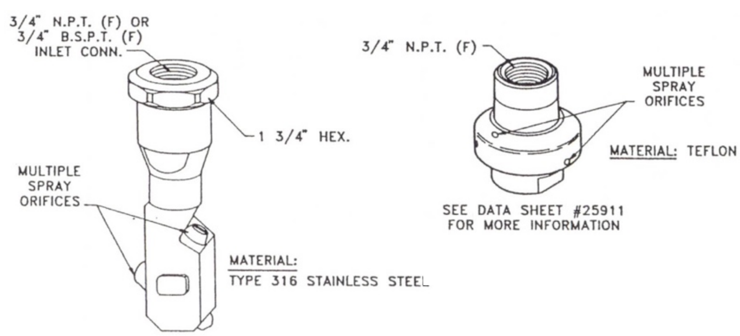

Figure 2.2.2. Two types of 360-degree tank rinse nozzles.

2.3 Minimizing Pesticide Drift

Spray drift of pesticides is an important and costly problem facing pesticide applicators. Drift can result in damage to susceptible off-target crops, environmental contamination to watercourses and a lower than intended rate to the turfgrass, thus reducing the effectiveness of the pesticide.

There are two types of drift, airborne drift, often very noticeable and vapor drift. The amount of vapor drift will depend upon atmospheric conditions such as humidity, temperature and the product being applied and can occur days after an application is made. Drift is influenced by many inter-related factors including droplet size, nozzle type and size, sprayer design, weather conditions and last but not least the operator.

2.3.1 Droplet Size

Lower spray volumes can result in smaller droplets that enhance leaf coverage although there is a limit to droplet size due to drift. Droplets under 150 microns generally pose the greatest hazard; droplets less than 50 microns have insufficient momentum for impaction as they remain suspended in the air indefinitely or until they evaporate. Research in England concluded that a 100-micron droplet takes 11 seconds approximately to fall ten feet in still air; when a similar size droplet is released into a 5mph wind it will drift about 75 feet before hitting the ground.

The higher the operating pressure, the smaller the droplet. Conversely, low pressure produces large droplets that may bounce off the target. Certain spray surfactants can change the droplet spectrum, reducing the number of driftable droplets.

2.3.2 Nozzle Type and Size

Correct nozzle selection is one of the most important yet inexpensive aspects of pesticide application. A nozzle's droplet size spectrum determines deposition and drift.

Conventional flat fan nozzles fitted to a turfgrass sprayer produces droplets in the range of 10-450 microns. There are

25,000 microns in one inch. Drift is a concern with droplets less than 100 microns.

Increasing the Volume Median Diameter (VMD) will certainly reduce drift, but too large a droplet will bounce off the leaves to the ground.

Conventional flat fan nozzles
Nozzles with 80-degree angle produce coarser droplets than 110° at the same flow rate but 80° nozzles require the boom to be set at 17-19 inches; 110° nozzles can be set lower at 15-18 inches above the target. (The lower the boom, the less chance of drift). Spray quality is fine – medium at 15 - 60 psi.

Pre-orifice flat fan nozzles
The internal design of this nozzle reduces the internal operating pressure compared to a conventional flat fan resulting in coarser droplets (high pressure creates fine droplets, low pressure creates coarser droplets). Available as 80° or 110° nozzles. Spray quality is medium - coarse at 30- 60 psi. Drift-guard is a well-known trade name.

Turbo-teejet
A turbulence chamber produces a wide angle flat spray pattern of 150°. Spray quality is medium – coarse at 15- 90 psi. Nozzles can be set at 15-18 inches above the target.

Turbo-Turfjet
This nozzle produces a very coarse droplet, ideal for liquid fertilizers. This nozzle works at pressures up to 75 psi and can be set at 20 – 40-inch nozzle spacing.

Air induction nozzles
Air induction, air inclusion or venturi nozzles are flat fan nozzles where an internal venturi creates negative pressure inside the nozzle body. Air is drawn into the nozzle through two holes in the nozzle side, mixing with the spray liquid. The emitted spray contains large droplets filled with air bubbles (similar to a candy malt ball) and virtually no fine, drift-prone droplets. The droplets explode on impact with leaves and produce similar coverage to conventional, finer sprays.

Air induction nozzles reduce drift even at higher pressures of 80-90 psi. They are only available at 110° fan angles so boom height may need to be adjusted to 15-18 inches.

The use of adjuvants will certainly help create bubbles and trials in the USA and Europe confirm this.

Air induction nozzles are more expensive than a conventional flat fan tip, although field results show greatly reduced drift and improved product deposition.

Manufacturers of air induction nozzles include:

Greenleaf TurboDrop nozzles consist of two primary components - the venturi air aspirator and the exit pattern tip. A ceramic orifice in the venturi determines the flow rate of the complete assembly. The venturi is ISO color coded to designate flow rate. The exit pattern tip does not affect flow rate: it is only used to form the desired spray pattern. Pressure range is 40-120 psi.

Spraying Systems Tee Jet Air Induction (AI) comprises a plastic body with a steel tip, rated for 30 to 100 psi. They are plastic, single-piece construction.

Hardi ID air induction is similar in construction to Spraying Systems AI nozzle; it is a one piece plastic nozzle.

Albuz is similar in construction to Spraying Systems AI nozzle; it is a one piece plastic nozzle with a ceramic tip.

Lechler ID an all plastic construction with removable venturi insert. 40 –100 psi range.

2.3.3 Sprayer Design

Shields are better at targeting the spray into the grass, reducing drift and increasing deposition. They vary from the simple to the complex. Shielded sprayers allow managers to apply pesticides in variable weather conditions.

2.3.4 Sprayer Calibration

Correct calibration will ensure that all the nozzles are discharging the correct amount of liquid at the correct distance and angle to the target and at the correct forward speed.

2.3.5 Weather

Wind speed and direction, relative humidity, temperature and atmospheric stability affects drift. Applying the correct product to the correct target at the correct time with the correct equipment is the key to good spraying.

2.3.6 Management Strategies to Reduce Drift

Before spraying:

1. Train the operator to use the sprayer correctly under your conditions.
2. Plan the spraying operation; consider the use of spray instruction cards as a good management tool.
3. Read and follow the pesticide label.
4. Select the correct nozzle for the target. Adjust the size and position of the nozzles to achieve correct distribution within the grass canopy,
5. Consider the use of sprayer nozzles which direct the spray to the target.
6. Consider spray additives to reduce drift.
7. Improve spraying logistics to ensure adequate time to spray within 'ideal' conditions.

8. Only spray when weather conditions are ideal; avoid spraying on days when conditions are favorable for atmospheric inversion or wind drift.
9. Calibrate the sprayer with water to ensure that everything is working correctly.

During spraying:

1. **Stay alert**: ensure the spray is not allowed to drift on to non-target areas and watch for changes in wind speed and direction.
2. Keep spray pressure as low as possible and ensure an accurate gauge is used.
3. Maintain a constant speed and pressure. If an automatic regulator is fitted, remember, small increases in speed result in large increases in pressure.
4. Avoid spraying near sensitive crops or watercourses; use a buffer zone.

2.4 Sprayer Preparation

A morning or afternoon spent fine-tuning your sprayer will be time well spent. The sooner one starts on pre-season maintenance the better as it also allows the local machinery dealer to get spare parts before the season starts. The cost of a new set of nozzles, pressure gauge or check valve diaphragms is soon recovered after a few hours of correct spraying.

A safe, well maintained sprayer, will work better, minimize waste and be more efficient.

CAUTION

- **Take great care when adjusting a sprayer while the engine is running.**
- **Engage the handbrake when leaving the seat.**
- **Ensure protective clothing is worn to avoid contamination.**

2.4.1 The Power Unit

The power unit must always be powerful enough to operate the sprayer efficiently under all working conditions. The air cleaner should be cleaned, the engine oil and filter changed if necessary. Tire pressures should also be checked.

2.4.2 The Operation of the Sprayer

Partially fill the tank with clean water and move the sprayer to a contained impervious surface. Remove the nozzles. The wearing of a coverall, gloves and a face visor when working with the sprayer is recommended as the sprayer may be contaminated. Engage the drive and gently turn the shaft, increasing speed slowly to operating revs. Test the on/off and pressure relief valves, and check the agitation system. Flush through the spray lines, then switch off the sprayer. Refit the nozzles and check the liquid system again for leaks.

The checklist…

Hoses

check…

- ❑ for splits, chafing and cracks, particularly where booms fold
- ❑ connections to ensure they are water-tight

Filters

check…

- ❑ for missing filter elements and seals
- ❑ for leakage
- ❑ for blocked or damaged filters
- ❑ correct filter for nozzle size

Tank

check…

- ❑ for fractures and any other damage
- ❑ the tank sits securely in its mount
- ❑ the agitation is working
- ❑ the tank is clean

Controls

check…

- ❑ the control circuitry (electrical, hydraulic or air) for correct operation
- ❑ valves for both internal and external leaks

Pump

check…

- ❑ oil levels and leaks
- ❑ the air pressure in the pulsation chamber (if fitted) is at the recommended level
- ❑ the pump rotates freely

Pressure Gauge

check…

- ❑ the pressure gauge needle doesn't fluctuate when the nozzles are delivering the correct amount of chemical per unit time while spraying
- ❑ the pressure gauge needle returns to zero when the sprayer is switched off

Boom

check…

- ❑ boom movement and stability
- ❑ the boom folding mechanism
- ❑ the height adjustment mechanism
- ❑ the break backs for correct operation

Boom Piping

check…

- ❑ the condition of all pipework
- ❑ the nozzle bodies for damage or loose fit
- ❑ for any damaged units, and replaced them
- ❑ for leaks under pressure

Check valves

check…

- ❑ damaged diaphragms and seats
- ❑ all valves stop liquid flow from the nozzles when sprayer switched off

Nozzles

check…

- ❑ all nozzles on the boom are the same
- ❑ all nozzles are in good condition, with no evidence of streaks or irregularities in the spray pattern
- ❑ all nozzles are clean and free from obstruction (note: clean with a soft brush or airline – don't damage nozzles by using wires or pins)
- ❑ all nozzles deliver to within + or - 5% of the manufacturer's chart value

Electronic controllers

Where your sprayer has automatic controllers to monitor the speed of the sprayer and the flow, pressure and area sprayed,

check…

- ❑ they are in good condition and properly maintained
- ❑ they are frequently calibrated for accuracy
- ❑ for leaks, blockages, variations in pressure or any minor damage during spraying

Routine maintenance

The following checks should be carried out routinely:

check…

- ❑ all hoses are tightly connected and free from sharp bends; cracked or damaged hoses
- ❑ must be replaced
- ❑ all controls move freely and are fully adjustable
- ❑ pump can be turned over by hand
- ❑ air pressure in pump accumulator (if fitted) is correctly adjusted
- ❑ drain plugs and clean filters are in position
- ❑ tires are sound and correctly inflated; wheel nuts are tight

2.5 Distance Learning

Web Pages:
Application technology at Cornell University:
web.entomology.cornell.edu/landers/pestapp/index.htm

Nozzles on the net:
www.c-spray.com
www.delavanagspray.com
www.hardi-us.com
www.hypropumps.com
www.lechlerusa.com
www.teejet.com
www.turbodrop.com
www.wilger.net

Nozzle testing:
www.gemplers.com/product/167823/Digital-Sprayer-Calibrator-0-100-GPM
www.wilger.net

Distance learning courses:
Beginning Farmer Program
moodle2.cce.cornell.edu

- Effective Spraying with backpack sprayers for organic growers
- Effective Spraying with boom sprayers for organic growers

Note: No fee, no DEC credits awarded

Pesticide Safety Education
pmepcourses.cce.cornell.edu

- Effective Spraying with Backpack Sprayers
- Effective Spraying with Boom Sprayers

Note: A fee is applied and DEC credits awarded

3 Turfgrass Culture

3.1 Introduction

Turfgrasses have many benefits often referred to as ecosystem services such as cooling and attenuating dust and noise. Additionally, in areas where pavement and other impervious surfaces dominate the landscape, turf can reduce runoff and function as a water purification system. As a recreational surface, turfgrass is cost effective, resilient and capable of minimizing injury. Finally, there are the well-being benefits of a well maintained landscape that includes lawn areas, especially in heavily urbanized areas.

A significant amount of turfgrass research has concluded that when managed properly, turf fertilizers and synthetic chemical pesticides do not pose a significant threat to water quality or human health. Still, answers to concerns regarding direct human exposure to chemical pesticides remain inconclusive. Every effort should be made to minimize the use of pesticides and when using them, apply them correctly.

Efforts to reduce chemical use on turf should include an understanding of how turfgrass grows and responds to management. Turf management requires that the professional manager pay particular attention to selecting properly adapted turfgrass species, implement management practices that promote a vigorous and resilient turf, and identify environmentally compatible pest management programs.

Another major consideration is the expectation of turf quality and use. It becomes especially important to be reasonable about visual quality expectations based on the function of the turf. For example, it is difficult to maintain high visual quality under intense foot traffic often associated with but not exclusive to athletic events without significantly increasing maintenance programs and concomitant economic costs.

Environmentally compatible turfgrass management requires consistent and vigilant care. Vigorous and resilient plants grow in fertile, well-drained soils. Therefore, the foundation of environmentally compatible care involves good soil physical and chemical management. This is most effectively accomplished during turfgrass establishment and before renovation. It is the first step in an integrated pest management (IPM) approach (as defined in section 3.4).

Maintaining an environmentally compatible turf – assuring that it be more competitive against insect, disease, and weed pests – requires a thorough understanding of the physical and chemical aspects of soil as well as the biology of grass plants and pests. It also requires an understanding of the dynamic relationship between an organism and its environment. Turf's essential "organism" is the grass plant. Its environment includes the soil, light, temperature, available water, associated flora and fauna, and humans. Turf management practices affect both the grass plant and its environment. For instance, mowing a turf below its adapted height weakens the plant and increases the amount of light contacting the soil. This causes the soil temperature to rise and can promote weed growth.

3.2 Selecting Turfgrasses

Grasses differ in their ability to adapt to soil and air temperatures, soil fertility, moisture and pH as well as to mowing, traffic and pests. When selecting a grass, refer to www.ntep.org for site-specific data on the major cool season turfgrasses. Selecting a well-adapted species is the first step in reducing overall reliance on chemical pesticides.

Visually, grasses differ in leaf width (texture), growth habit (bunch-type, rhizomatous, stoloniferous), density and color. This variability exists between and within each species, which partially explains the large number of varieties available for each species.

Important cool-season turfgrass species include Kentucky bluegrass, creeping bentgrass, perennial ryegrass, tall fescue and the fine-leaf fescues. These grasses can be classified as high, medium and low maintenance species based on the amount of mowing, fertilizer and water required for optimum performance.

A new iBook is available with the latest recommendations for NYS Turfgrass Managers for selecting the proper species and varieties: http://turf.cals.cornell.edu/resources/turfgrass-species-and-variety-guidelines-for-nys/.

3.2.1 High Maintenance Species – Golf, Sports and Lawn Turf

Kentucky bluegrass (*Poa pratensis*) is an important high-quality turfgrass in northern climates for lawns and sports turf. It is a well-adapted perennial species that produces rhizomes (underground lateral stems), which enhance the species' ability to form a thick mat or sod.

Kentucky bluegrass grows most successfully in well-drained sites receiving full sun and regular fertilization. However, under ideal conditions 45 to 90 days are required to establish a dense turf from seed, therefore many Kentucky bluegrass areas are established from sod. Improved aggressive compact or Midnight-type varieties require supplemental irrigation to avoid the summer dormancy associated with warm, dry conditions. Older common varieties such as Bartitia and Kenblue, however, have been successful with no irrigation in northern climates.

Many improved Kentucky bluegrass varieties, specifically Midnight or Compact Aggressive types, demand high maintenance, regular and consistent mowing, fertilization and irrigation. These elite varieties are often the primary component of sod. Therefore, with limited varietal options sodded areas tend to be inherently demanding of intense maintenance. The inability to meet these high quality demands can result in significant decline in turf quality. Furthermore, turf quality decline can lead to increased weed invasion and thin turf. Therefore, be mindful when selecting Kentucky bluegrass types and be sure resources are available to meet maintenance demands.

The major pest problems of Kentucky bluegrass include fungal diseases such as leafspot, dollar spot, summer patch and necrotic ringspot as well as root-feeding insects such as white grubs and surface feeders such as billbugs.

3.2.2 High Maintenance Species – Golf Turf

Bentgrass species include creeping (*Agrostis palustris*), colonial (*Agrostis tenuis*) and velvet (*Agrostis canina*). They are primarily used for golf, tennis and lawn bowling turf. Bentgrasses spread by aboveground stems known as stolons and are most successful mowed less than 0.75” with reel-type mowers

The bentgrasses are adapted to acidic, infertile soil. However, they can adapt to pH levels in excess of 8.0 The most common creeping bentgrass variety is Penncross however new varieties such as Penn A and G series as well as T-1, Tyee, and MacKenzie have increased shoot density that allows for mowing below 0.125” and have improved disease resistance, especially for dollar spot. Dollar spot resistant varieties include L-93, LS-44, Independence and Declaration.

The most common disease of creeping bentgrass is dollar spot and insect problem is cutworm. In general, creeping bentgrass is managed in a mixed stand with annual bluegrass that reduces turf quality and increases fertilizer and pesticide use. Annual bluegrass (*Poa annua* and *Poa annua reptans*) is very susceptible to a variety of diseases and insects.

Annual bluegrass, an invasive winter annual weed, successfully adapts to intensely managed turf and following initial invasion of the true winter annual type, has the capacity to become more perennial. Perennial forms are dense and produce significantly less seedheads.

Annual bluegrass is the primary turfgrass species on most northern golf courses. It is plagued with environmental and pest stress, most notably winter injury, summer decline and a myriad of fungal pathogens such as anthracnose basal rot and dollar spot as well as surface feeding insects such as Annual bluegrass weevil.

3.2.3 Medium Maintenance Species-Golf, Sports and Lawn

Turf-type tall fescue (*Festuca arundiacea*) is a bunch-type grass with substantially wider leaves than fine-leaf fescues. It is an exceptionally deep-rooted grass, a trait that allows it to persist under drought conditions. The deep rooted nature of tall fescue has been shown to reduce damage associated with soil insect larvae feeding. It is tolerant of wear. To be successful in a heavily trafficked turf that creates voids, it requires regular seeding due to its bunch-type growth. Since it is less winter hardy in the seedling stage, tall fescue should be sown in the late spring (May/June) or late summer (August).

Turf-type tall fescue has historically been susceptible to brown patch and Pythium and may suffer from rust infestations. However, improved finer textured varieties have shown excellent resistance to both brown patch and Pythium. Proper nitrogen fertilization is vital to avoid and minimize these pest problems.

3.2.4 Medium Maintenance Species – Golf, Sports and Lawn

Perennial ryegrass (*Lolium perrenne*) is a bunch-type grass lacking the lateral growth of rhizomes and stolons. Rather, each plant gets thicker at the base with side shoots called tillers. This makes ryegrass reliant on overseeding in high traffic situations such as sports fields. Ryegrass germinates from seed in two to four days and under ideal conditions provides a uniform turf within two weeks. It is most successful when it receives regular care in sites that are fertile, well-drained and in full-sun.

The major pest problems of perennial ryegrass include fungal diseases such as red thread, rust, brown patch, and Pythium blight. Gray leafspot has become a damaging disease of perennial ryegrass. Breeders have developed a few resistant varieties such as Paragon GLR. Additionally, many ryegrass varieties contain endophytic fungi. Referred to as endophytes, the fungi live in association with the grass plant in the leaf sheath. Endophytes produce natural chemicals that deter surface-feeding insects such as chinch bugs and sod webworms, but have no effect on white grubs or other root feeders. While it is difficult to determine exact levels of endophytes, it is wise to consult seed supplier to determine if variety has demonstrated infection in trials.

3.2.5 Low Maintenance Species – Golf and Lawn

The fine-leaf fescues include strong or slender creeping red fescue (*Festuca rubra*), chewings fescue (*Festuca rubra* var. commutata), hard fescue (*Festuca longifolia*), and sheep fescue (*Festuca ovina*). The fine-leaf fescues are characterized by a medium to dark green color, narrow needle-like leaves and primary bunch-type, non-spreading growth (except for creeping red fescue, which can produce a mat from its rhizomes). They are exceptionally slow growing, requiring little to no supplemental fertilizer and are particularly tolerant of shade.

The Hard and Sheeps fescues are the true low maintenance species in this group. These species are often found as major components of "native", "low mow", "slow grow" mixes. These mixtures are well adapted to low maintenance and can be mowed from 2" to 6" and even develop into a meadow grassland. For these types of plantings, it is wise to select varieties that have a history of endophyte infection to minimize problems associated with surface feeding insects.

The fine-leaf fescues are well adapted to infertile, acidic soils and, compared to other cool-season grasses, are most tolerant of shaded conditions. As a group, the fine fescues are not tolerant of traffic, except under extremely dry conditions and, similar to ryegrass, these bunch-type grasses do not fill in open spaces. The fine fescues are the greatest thatch producing cool season turf. To minimize this problem limit N fertility.

The fine fescues have few major pest problems except during persistent wet conditions when red thread and leaf spot can be severe. Similar to the ryegrasses, certain fescue varieties have endophytes that repel surface-feeding insects such as chinch bugs and sod webworms, but they are susceptible to infestations of white grubs, which feed on the roots.

3.3 Cultural Practices

3.3.1 Mowing

Mowing is the most fundamental of all cultural maintenance practices and has the most significant influence on turfgrass performance. For example, by lowering the height of the cut below the acceptable range for each turfgrass species and root growth declines, thereby reducing the plant's ability to extract water and nutrients from the soil. Furthermore, close mowing increases the level of maintenance required for acceptable quality.

For many years we have recommended following the 1/3 rule, i.e., never to remove more than 1/3 of the leaf tissue with every mowing. However, upon further examination and in response to reduce mowing in effort to reduce carbon emissions, it appears there is flexibility with this issue.

Research with several cool season species such as perennial ryegrass and tall fescue has shown that you can safely remove up to 70% of the leaf tissue with each mowing provided you stay within the mowing tolerance range for the species. This should reduce overall mowing needs without reducing plant health. In fact, it is always best to mow lawn grasses as high as aesthetically feasible and where traffic tolerance is not primary concern. Higher mowing heights allow for longer intervals between mowings as well as allowing for a canopy to disperse clippings.

Still, grass clippings contribute nutrients to the soil when they are returned. They should be left on the turf as long as there are no clumps to smother the grass below.

When mowing height is increased, the canopy shades the soil and the soil surface gets cooler. In fact, studies show fewer weeds (broadleaf and grassy) as a result of mowing heights at the higher end of the species range. In addition, when taller blades of grass shade and cool the soil, seeds of warm-season grassy weeds such as crabgrass (*Digitaria* spp.) are less likely to germinate. In fact, several studies have shown 30 to 70 percent reduction in crabgrass infestations by raising the mowing height from one inch to 3 inches.

Extensive research with reel mowing of putting greens has found that raising the mowing height above 0.125", double cutting and rolling maintains ball roll distance and reduced basal rot anthracnose. Furthermore, mower set-up issues such as frequency of clip and bedknife position also can influence severity of anthracnose when not closely monitored.

3.3.2 Fertilizing

Proper nutrition is as vital for plant health as a balanced diet is for human health. A person who eats more of the wrong foods and not enough of the right foods has a greater chance of experiencing poor health, especially when he or she is also under stress or exposed to germs. To maintain a healthy turf, a proper amount of nutrients must be available. Fertilizers help supply nutrients to the turf necessary to maximize plant health.

In general, soil testing can serve as the basis for fertilizing. However, there is concern recently that current soil testing methodology overestimates turf nutrient needs. If a soil test indicates adequate nutrients in the soil, fertilizing provides no benefit and can be, in the case of phosphorus, potentially detrimental to the environment. If fertilizer lands on paved surfaces or is applied and not watered in properly, it can be washed into storm drains and contaminate any body of water where the storm drain discharges.

Nitrogen is the primary nutrient for the growth of dense turf. It is important to several physiological aspects of plant growth, especially shoot and root growth. Improper timing and application rate of nitrogen can result in excessive shoot growth at the expense of root growth – a typical result of early spring applications of water-soluble nitrogen fertilizers.

Several states have begun to review nitrogen application rates in an effort to reduce the risk to water quality. Current research underway at Cornell University suggest that on sandy loam soils no more than 0.7 lbs of N per 1000 square feet should be applied in a single application. Additionally, on sand-based rootzones in excess of 85 percent sand, the application rate should be no more than 0.5 lbs.

Research has shown that high rate (1 pound of actual N per 1000 square feet) applications of nitrogen made during the Spring surge of top growth do not enhance green up as well as fall applications. In addition, when the soil warms (the actual cause of spring turf green up) and water-soluble nitrogen becomes quickly available to the grass, plants produce shoot growth at the expense of root growth. Thus, over-fertilized primarily spring-fed plants are more stressed going into hot, dry summers because their roots have grown less.

On some occasions spring fertilization is necessary to promote increased turf density after winter's ice and snow destroy some of the grass plants. Spring fertilization also will benefit turf areas that have not been fertilized in late fall. Turf can successfully compete for space before summer weeds emerge if fertilizer increases turf density. Ideal spring fertilization rates would be at half to one quarter full application rates or 0.25 to 0.5 pounds of actual nitrogen per 1000 square feet.

The most important fertilization for lawn turf grown on a loamy soil is around the Labor Day holiday in early September. High quality golf and sports turf that receives regular light fertilizer applications during the season can maintain that approach until top growth ceases. Historically, we have recommended late season high nitrogen applications of fertilizer, however due to water quality concerns from these late season applications research indicates no more than 0.25 to 0.5 lb of N per 1000 square feet should be applied, especially in southern NY locations where soil freezing is not assured. Fertilization in non-frozen soil areas should cease by mid-October.

In addition, there is no evidence that high rates of potassium beyond that considered to be adequate enhance winter hardiness. In fact, current research at Cornell University indicates that addition of any K fertilizer can lead to increased pink and gray snow mold. Therefore, avoid K fertilization unless deficiency symptoms are evident.

Turf grown on sandy soils should use a high percentage of slow-release nitrogen or light frequent rates of water soluble nitrogen to minimize leaching past the root zone. As turf ages organic or labile N accumulates and will contribute to the plant N needs. Therefore, N fertilization programs should also be adjusted based on the age of the lawn.

3.3.3 Irrigation

Turf in northern climates typically requires supplemental irrigation for a few months in the summer. It is possible to maintain a dense turf without supplemental watering, but it will not be high quality turf for the entire season. Historical evapotranspiration and rainfall models indicate turf in the Northeast would only require supplemental irrigation in the June through August time period.

When supplementing with irrigation proper application is critical for maintaining plant health during stressful periods. The most important guideline is to apply a percentage of what the plant and soil have lost to evapotranspiration. Often this is approximately one inch of water per week in the absence of rainfall, but it is wise to account for the water storage available in the soil. To avoid runoff, water should be applied at the rate the water will penetrate in the soil.

The best time to apply supplemental watering is early in the morning. At this time evaporation rates are low, which improves efficiency, and the grass dries more quickly. It is also important to minimize the length of time grass blades are wet to reduce the occurrence of fungal diseases.

It is normal for cool-season grasses to go into summer dormancy, brought on by low rainfall. Studies have shown that as little as one-tenth of one inch of water over a three-week period is all that is required to keep them alive. Either too much or too little water can weaken the plants, making them more susceptible to pest problems and less likely to recover when cool, moist conditions return.

Several studies have been published in the last few years investigating the role of irrigation on disease incidence. It was concluded in these studies that more frequent light irrigation leads to severe brown patch and dollar spot problems.

3.3.4 Problem Solving

Solving turf problems begins with a thorough understanding of the turfgrass plants and their environment. These may result from poor growing conditions or excessive use, which then leads to reduced turf health. The first step in problem solving is to determine the poor growing condition causing the weak turfgrass:

1. Is it low light?
2. Is it poor drainage?
3. Is it compacted soil?
4. Is there still a problem after an unfavorable condition was remedied?

The most common cause of poor turf is poor growing conditions. Maintaining adequate light levels of at least four hours of direct sunlight per day is a good start. Next, assure adequate surface and if needed subsurface drainage. Chronically wet root zones will increase compaction thereby weakening the root system and compromising plant health.

3.3.5 Weeds

A significant weed infestation can detract from turfgrass visual quality, but often poses no functional or environmental problem. **Weeds are best kept under control through prevention**. A chronic weed infestation is often the result of turf management practices that reduce the ability of grass plants to grow competitively, and resist insect and disease pests. Optimizing soil fertility results in a denser, more competitive turf. The most effective management strategy with respect to weeds is multi-faceted:

- Understand weed biology and identify problem weeds.
- Carefully evaluate site conditions to determine if they are conducive to optimal turf growth.
- Focus on maintaining a dense turf.

3.3.6 Diseases

Fungi cause most turf diseases. The fungal pathogens that infect grasses live mostly as saprophytes, feeding on dead or decaying organic matter, until environmental conditions favor infection.

Most turf disease occurs when the grass plants are environmentally stressed and are in a weakened condition which could favor pathogen growth.

Many products such as microbial inoculants, composts, and other bio-stimulant products claim to prevent or control diseases. While some research indicates that composts and inoculants can suppress certain diseases, the majority of products have not been tested under controlled conditions. Nevertheless, it might be worth testing the performance of a small amount of material on a limited area of your turf. A dense turf, planted with a disease-resistant variety, in an ideal growing environment is the best defense against turfgrass diseases.

3.3.7 Insects

Insects are abundant in nature and make up a substantial portion of all the forms of life on this planet. In fact, the turf environment sustains high populations of insects. Very few are damaging.

Grass plants can tolerate substantial insect feeding. The principles of an IPM program are based on the principle of insect population threshold. The threshold is the number of insects per unit area, beyond which the grass is significantly injured. In early spring, for example, an actively growing turf can tolerate feeding by 10 to 15 white grubs per square foot of turf. In late August through October, larvae (or grubs) of the Japanese beetle surface to feed on grass roots and should be monitored to determine if control is necessary.

Damage by surface-feeding insects occurs from June through August. One way to inspect for these insects is to apply a solution of soapy water to a small area at the periphery of the damaged turf; the insects will come to the surface within a few minutes.

Perennial ryegrass, fine-leaf and tall fescues enhanced with endophytes have been shown to be resistant to surface-feeding insects. One good result of the association between the endophytes and the grass plant is that a natural chemical is produced, which is present in the leaf sheath and deters insect feeding. If a stand is lost to a surface-feeding insect, every attempt should be made to introduce an endophyte-enhanced variety to prevent future damage. Studies have shown that as little as 20 percent endophyte enhanced grasses in a stand will significantly reduce damage to turfgrass areas.

3.3.8 Summary

Environmentally compatible turfgrass management programs use natural resources (i.e. water, fertilizer) efficiently to preserve the quality of the immediate and nearby environment. All parts of turf management are intimately linked. Altering one component ultimately influences the performance of another.

- First, be sure to understand the physical and chemical aspects of turf soil.
- Next, select grass plants that are adapted to the region, resistant to major pest problems and can meet your expectations for quality and use.
- Next, maintain turf density through timely and proper cultural practices.
- Finally, manage weeds, diseases and insect pests, while minimizing the impact of your methods on the environment.

The result will be a dense turf that looks good, performs well and benefits the environment.

3.4 Integrated Pest Management

Cornell's *Guide for Commercial Turfgrass Management* provides turfgrass managers with information on the legal and appropriate use of pest management practices and products. The focus is primarily on pesticide options, the legality and availability of which change frequently. However, this guide should only be used in the context of a complete, site-specific, integrated pest management (IPM) program. Such a program cannot be detailed within the confines of this book, but an introductory IPM discussion is presented below. In addition, the online version of these guidelines at ipmguidelines.org offers more IPM information by linking to resources such as turfgrass cultural practices, species and cultivar selection, diagnostics, and biological pest management. The printed version is a handy, quick, field reference for managers, but readers are encouraged to also explore the additional resources presented online.

IPM is a decision-making process that strives to make best use of all available management tools, including cultural, biological, mechanical, environmental, and chemical methods. IPM is effective, economical, and minimizes risk to the environment and human health. IPM is also known as integrated turfgrass management, best management practices or plain old common sense. IPM is also the basis of a good organic program, even though synthetic chemical pesticides are not included in those programs.

Definitions of IPM are numerous, but most agree on the following goals:

Minimize: Losses to pests; costs; negative effects on human health and the environment; and pesticide resistance potential.
Maximize: Cultural, mechanical and biological pest controls; effectiveness of chemical pesticides (when they must be used); turfgrass quality; and populations of beneficial organisms.

Any decisions based on these criteria involve balance and potentially compromise, and depend on factors such as pest pressure, weather, quality demands and intended use of the area. Therefore, turfgrass managers select distinct IPM practices in various settings and circumstances. As practitioners, you know that IPM is diverse and cannot be applied according to "cookbook" recipes–it is a customized, proactive approach. The practice of IPM can be described in seven steps.

3.4.1 Plan

Successful businesses set goals and plan ahead. Likewise, good IPM requires good planning. Start with the big picture, such as “improve the environment with a quality turfgrass product”, and then work into finer details. Ask how you can improve the environment on your golf course or your customers’ properties, in the watershed, and in the community. Determine the current condition of the property. What grass and weed species are present? What are the soil conditions? What other pest problems are possible, and which are likely to occur? Consider the history from that property as well as from the local area.

A complete plan includes each of the six steps described below, and following it may require training a staff person on how to monitor and identify pests, attending educational sessions, or producing informative literature for customers. Plans should be flexible enough to incorporate new information and have contingencies for unexpected situations, such as invasion of a new or rare pest.

3.4.2 Monitor

Turfgrass areas should be monitored on a regular basis to assess health of the turfgrass planting, as well as signs and symptoms of pests, and other stress factors such as drought and nutritional deficiency. Proper identification of pests (including weeds, insects, diseases and vertebrates) and underlying cultural problems is essential. Know how to identify each pest species, the season when they occur, the conditions that favor them, and how they can be detected. Awareness of potential and probable pest problems is key to being able to prevent and monitor for them.

Pests must also be quantified to determine if populations are rising or declining, if thresholds have been reached, and whether previous control measures were successful. The pest stage (e.g. weed seedling, insect pupa) is also important for determining if and when intervention may be appropriate. Lawn care professionals can enhance their monitoring efforts by using lawns with known histories of problems as early indicators in individual neighborhoods. Likewise, managers of golf courses, institutional grounds and sod farms can follow specific indicator areas within the larger property.

Armed with knowledge of both pests and site, you should monitor or “scout” turfgrass areas on a regular basis. For low maintenance areas, that can be weekly or monthly, depending on the current pest pressure, pest biology, time of year, and expected use of the area. Higher maintenance areas need a minimum of weekly monitoring, with putting greens requiring daily examination. Disease and insect problems can appear relatively quickly and frequent monitoring can provide an early warning of problems when conditions are conducive for that pest, especially in areas with a history of the problem. Weeds, on the other hand, invade and grow more slowly and can be monitored as infrequently as three times a year.

3.4.3 Manage

Sound horticultural practices are fundamental to growing and maintaining healthy turfgrass, and healthy grass is more resilient to pests. Maintain the turfgrass areas with the best cultural management strategies that are feasible for the site, including optimal grass species and variety selection, watering and mowing practices, and fertility inputs based on soil or tissue testing. Minimizing turfgrass stress, selecting pest-resistant grasses and proper maintenance of equipment have the greatest impact on reducing pest problems.

3.4.4 Analyze

IPM is a knowledge-based decision-making process, and the use of action or treatment thresholds is one of its hallmarks. Thresholds are flexible guidelines, usually defined in terms of the level of pest abundance or damage that can be tolerated before taking action, and are based on numerous aspects of the biology of both pest and plant. IPM managers apply thresholds to plan short and long term pest management actions and strategies for each turfgrass area, after considering monitoring data, current and predicted weather conditions, turf value and customer expectations. This analysis is an ongoing process that allows managers to make timely and appropriate decisions for individual areas throughout each growing season. The determination that a pest problem warrants intervention, such as the use of a pesticide, is part of a thorough analytical process.

3.4.5 Intervene

At times the monitoring and critical analysis process will reveal a problem that needs remediation. At this point, the professional intervenes with a cultural, physical, biological, or chemical control tactic. The cultural practices discussed elsewhere in these guidelines are mainly preventive, but can sometimes be used to minimize the effects of a pest outbreak. Midnight mowing is an example of a physical tactic that has effectively reduced cutworm populations on putting greens, and may also be useful on higher cut turf. Biological controls have received a great deal of attention in the past 20 years, partly due to the decline in chemical options. Several products are now available and legally registered as pest control products, and are listed in the appropriate pest tables. Remember that biologicals tend to be more pest and climate specific than traditional chemical pesticides, and therefore must be appraised on a case-by-case basis. Examples include *Trichoderma harzianum* and *Bacillus licheniformis* for disease management, and entomopathogenic nematodes and *Bacillus thuringiensis* for insect control.

Application of chemical pesticides, a common intervention for many managers, is the last option for an IPM practitioner. Close attention to the monitoring and analysis of individual areas often allows for spot treatments rather than whole area treatments and the use of lower toxicity treatments, before pests reach high levels. An IPM practitioner will consider all approaches and select the least disruptive option that will be effective.

The Environmental Impact Quotient (EIQ), described in Section 1.12, can be used to select a low toxicity pesticide. Pesticide resistance should also be minimized by rotating modes of actions. Resistance codes are listed in Table 9 of this guide.

3.4.6 Keep Records

Many benefits of IPM are lost if information is not recorded. All considerations from the analysis process should be documented, as well as the cultural practices and intervention tactics employed. Professionals should keep good records of cultural practices; turfgrass health; pest incidence, identity, and severity; and all intervention tactics, especially the use of pesticides. These records are critical for in-season decision-making as well as historical documentation of pest problems and efficacy of actions taken. From this base, personalized thresholds can be developed and the effectiveness of treatment decisions evaluated. Whether you spent $500 or $50,000 on pest control last year, you should know if it was worthwhile and necessary.

The use of *Trac Software for Turfgrass* can improve the ease and accuracy of your record keeping. There are specialized files for golf, lawn care, grounds management and sod farms. Each file contains a listing of approximately 100 pesticides registered in New York State for that turfgrass setting. Visit nysipm.cornell.edu/trac to learn more about the software and how to obtain it.

3.4.7 Communicate

Good communication with staff, customers, and community members is an essential aspect of IPM. Regardless of who is designated to monitor, all staff should be aware of pest problems and management activities. All employees should be encouraged to report potential problems, and IPM training should be provided to as many staff as possible. The IPM approach also needs to be conveyed to customers, whether they are homeowners, golfers, or neighbors. The turfgrass professional should articulate to customers how his/her expertise along with information gleaned from monitoring and a scientific knowledge base combine to create a customized, site-specific IPM program. Describe IPM in promotional literature and on your website. IPM efforts pay off many times over when communicated among staff, to customers, and the community.

4 Plant Growth Regulators

4.1 Overview

Plant growth regulators (PGR) are organic compounds, either synthesized in the plant or as an applied substance, that in very low concentrations can either increase or decrease plant growth. New York State regulates PGRs as pesticides, as many herbicides are classified as growth regulators and therefore, they are registered with the EPA.

Plants create biomass (leaves, stems, roots, flowers) by producing new cells from existing cells that divide (cell division). Cell division increases the number of cells. Once the plant has new cells, these cells must stretch or elongate to make new organs (leaves, roots, flowers) by a process called cell elongation. These processes are indirectly regulated by a plant hormone, gibberillic acid (GA). As GA levels increase, growth (division & elongation) occurs and the plant creates new biomass.

Turfgrass growth regulation began as an idea some 50 years ago in an effort to reduce mowing. One of the first products used successfully in turf was maleic hydrazide (MH). MH suppressed foliar growth and seedhead formation of roadside vegetation. More recently, mefluidide has been used primarily for *Poa annua* seedhead suppression on golf courses. Mefluidide is absorbed by the leaves, most effectively at the base of the leaves, and does not move through the plant. This makes thorough spray coverage essential. Once it penetrates the leaf it begins to primarily affect cell division with a lesser influence on cell elongation. Consequently, when it contacts a flowering stem (*Po*a seedhead) during formation, it causes it to distort and prevents seedhead emergence from the leaf sheath. Products with this activity are classified as **Type I growth regulators**, of which mefluidide is the most common.

Type II growth regulators act by influencing cell elongation, primarily through inhibiting GA synthesis. Products in this class include flurprimidol, paclobutrazol, ethephon and trinexapac-ethyl. Because these products primarily affect cell elongation and not division, the number of new cells is only slightly reduced while their ability to elongate is significantly altered. Increased number of smaller cells explains the altered morphology of the turf leaves (wider leaf blades) and the short stumpy appearance of the plants (reduced internode length – the distance between new leaves). There is also some experimental evidence that indicates stolons of treated plants become more prostrate and rosette-like (like a witch's broom).

Flurprimidol and paclobutrazol are both primarily root absorbed while trinexapac and ethephon are foliar absorbed. This is a significant strategic aspect in terms of the length and flexibility of regulation. The other significant factor in the use of PGRs is that they exhibit different degrees of regulation depending on the turf species.

The use of growth regulators in turf can cause significant reductions in turfgrass quality if not applied at the proper timing and at the proper rate to the proper turfgrass species, much like an herbicide. The most common uses of plant growth regulators are for mowing management, annual bluegrass seedhead suppression, and to selectively suppress and reduce populations of annual bluegrass.

4.2 Mowing Management

Plant growth regulation to reduce elongation of turf leaf blades can extend the time periods between mowing. Theoretically, this could reduce mower wear and tear, reduce fuel consumption, and minimize clipping handling problems. Additionally, with growing concern regarding carbon emissions contributing to climate change any reduction in mowing would be viewed as moving toward sustainability.

The effective use of plant growth regulators for mowing management depends on many factors: timing of the application (the earlier in the season the PGR is applied the greater the reduction), the turf species being treated (generally ryegrass and tall fescue require higher rates than Kentucky bluegrass and creeping bentgrass), and the rate and frequency of application.

In general, plant growth regulators can reduce mowing requirements by 40 to 60 percent without significant reductions in turfgrass quality. Environmental stress such as heat or cold can compromise turfgrass quality during regulation and should be considered prior to implementing a mowing management program.

Recent research has suggested the use of growing degree day models to properly time PGR applications. For example, by maintaining a consistent physiological interval the growth of the turf can be uniformly suppressed without the associated "rebound" effect. The rebound effect is described as turf growth that exceeds the growth of an untreated plant. Specific research with trinexapac indicates applications made on a base 32 GDD model every 200 units will maintain uniform suppression both for golf turf ball roll distance and general mowing reduction.

4.3 Annual Bluegrass Seedhead Suppression

As a winter annual weed, annual bluegrass is triggered in the spring to shift emphasis from vegetative growth (leaves, stems, roots) to reproductive growth (flowers that bear seedheads). This shift has biological and physical consequences. Biologically, tillers that produce a seedhead will die off resulting in a natural thinning of the stand. Physically, seedhead production when plants are mowed at or below 1/8 inch reduces the playing quality of putting surfaces.

There is a continuum of life cycle types of annual bluegrass found on golf courses. It ranges from the weedy winter annual type that grows in clumps and produces enormous amounts of seed to the perennial type that grows laterally and produces less seed. Putting greens in northern climates consist of annual types for several years and then almost exclusively perennial types after 15 to 20 years.

The key to high quality annual bluegrass putting surfaces in the spring is effective seedhead suppression. Specific plant growth regulators are able to suppress the seedhead and not kill the plant. In fact, studies have found that by not producing seedheads the plants are able to divert energy that would be used to form a seed and use it for overall plant health.

The traditional method of seedhead suppression in the spring in northern climates is performed with mefluidide and ethephon. Independent of the product used for suppression, application timing is the critical factor that determines the intensity and duration of seedhead suppression.

Research has shown the ideal timing for seedhead suppression with ethephon appears to be between 400 and 600 base 32 growing degree days and ideal timing for mefluidide is 500 to 650. The inclusion of trinexapac in a tank mix combination seems to extend the application window as well as the duration of suppression with both products. In most areas of New York, only two applications will be necessary for adequate suppression. Ideal timing for seedhead suppression programs can be monitored during the growing season at the ForeCast website http://www.nrcc.cornell.edu/industry/grass.

Mefluidide treated putting greens often sustain some injury, mostly to creeping bentgrass. Tank mixing mefluidide with iron generally reduces bentgrass injury; however, mefluidide rates often need to be increased to compensate for slight antagonism. Also, tank mixing mefluidide or ethephon with trinexapac has been shown to reduce the incidence of basal rot anthracnose. However, trinexapac alone does not suppress annual bluegrass seedheads.

Ethephon does not appear to produce the same amount of injury as mefluidide. However, there have been reports of "false crowning" of plants treated more than twice that can increase the likelihood of scalping. Again, tank mixing with trinexapac seems to minimize this problem.

4.4 Enhancing Annual Bluegrass

The predominance of annual bluegrass on golf and sports turf has led many to simply accept its invasion and develop cultural management programs to enhance performance. Annual bluegrass is a shallow-rooted, cool season grass that grows well in spring and fall, but suffers severe summer stress and winter injury. In addition, it is susceptible to a number of fungal diseases that require regular fungicide applications to maintain a quality turf.

Ideal management programs include regular fertilization, especially in cool months of the year, as well as light and frequent watering practices. Annual bluegrass will often thrive under normal mowing programs; however, mowing heights below 1/8 inch have been shown to increase the likelihood of basal rot anthracnose.

Trinexapac has been shown in many studies to improve the health and performance of annual bluegrass stands. Programs that make multiple low rate applications throughout the season have been shown to be most effective. In fact, it is vital to sustain an application protocol during the season as studies have shown that ceasing applications results in a "growth rebound" and compromises annual bluegrass health.

Current research indicates that trinexapac is rapidly metabolized under high temperatures when applied to the plant during summer months. This has often required increased rates or decreased application intervals. Research at the University of Wisconsin-Madison indicates application of Primo should be spaced no more than 200 base 32 growing degree days apart. Increasing the interval more than 200 GDD allows for the plant to release from regulation, thereby altering performance and plant health.

4.5 Selective Annual Bluegrass Suppression

Plant growth regulators have been shown to reduce annual bluegrass on golf turf without any significant disruption of play or reduction in turf quality. The benefits of less annual bluegrass include reduced winterkill, no unsightly seedheads, reduced N requirement, and a reduced severe disease spectrum.

The Type II PGR's paclobutrazol and flurprimidol have been shown to be the most effective in reducing annual bluegrass populations over a period of time. Higher cut creeping bentgrass turf on fairways tends to be a more conducive environment for reducing annual bluegrass compared to putting greens and tees with more chronic and focused surface disruption.

The most effective programs include multiple applications throughout the season that provide a cumulative reduction. Flurprimidol and paclobutrazol programs have been shown to reduce fairway populations as much as 70 percent in two years. This type of success is usually achieved when a comprehensive cultural management program of reduced fertility and irrigation plus overseeding programs to favor the more hardy and desirable creeping bentgrass turf are used.

4.6 Use of Growing Degree Days to Improve Growth Regulator Performance

The most commonly applied PGRs used on putting greens are *NYPrimo Maxx (trinexapac-ethyl), *NYTrimmit (paclobutrazol), and Cutless (flurprimidal). These products alter growth rate in two distinct phases. Following PGR application clipping yield becomes suppressed relative to non-treated turfgrass; the suppression phase. After a period of time the suppression phase ends and clipping yield increases to a level greater than non- treated turfgrass; the rebound phase. Researchers have found that the duration of the suppression phase is dependent upon air temperature. As air temperatures increase into the summer the length of the suppression phase decreases. This occurs because turfgrass plants breakdown PGRs, such as *NYPrimo Maxx, faster as air temperatures increase. This means that calendar based PGR re-application intervals are not efficient at maintaining yield suppression because the ideal re-application interval changes during the course of a growing season.

Growing degree day models are used extensively in traditional agriculture to estimate crop growth and development in relation to air temperature and recently have been used to estimate weed growth and development in turfgrass, i.e. *Poa annua* seed head formation (GDDTracker.net). To calculate GDD he high and low air temperature are averaged together, subtracted from a base temperature where metabolism is minimal, and added to values from the previous days.

A recent study measured daily relative clipping yield from a creeping bentgrass putting green treated with *NYPrimo Maxx every 100, 200, 400, and 800 GDD as well as every four weeks. The GDD was calculated in degrees Celsius with a base temperature of 0°C and began after the previous *NYPrimo Maxx application. After the GDD threshold had been surpassed (i.e. 200 GDD after *NYPrimo Maxx application), Primo was re-applied and the model was reset to zero. A spreadsheet program such as MS Excel can be used to track the progression of GDD after PGR application and convert temperatures to Celsius. Temperature °C=Temp °F-321.8
It was determined that the 400 GDD, 800 GDD, and four-week re-application frequency did not maintain season-long yield suppression. Rather the 100 and 200 GDD re-application frequencies maintained season-long yield suppression. The 100 GDD re-application interval resulted in a greater level of yield suppression than the other treatments. The 200 GDD re-application interval is the furthest *NYPrimo Maxx re-application interval to maintain yield suppression because the yield begins to transition into the rebound phase after 200 GDD. During a heat wave with high temperatures of 100°F and lows around 75°F (average day temp. 89°F) 200 GDD occurs in 7 days or less. This illustrates how *NYPrimo Maxx re-application interval needs to be adjusted depending upon air temperatures to avoid the rebound phase. As temperatures warm into the summer, Primo needs to be re-applied more frequently than it does in spring and fall to avoid the rebound.

The 200 GDD re-application interval is only meant for *NYPrimo Maxx applications to creeping bentgrass golf putting greens. Taller mowed turfgrass such as Kentucky bluegrass athletic fields are more sensitive to *NYPrimo Maxx and would have a different Primo GDD threshold. Some preliminary research on *Poa annua* putting greens found that the 200 GDD re-application interval is effective at maintaining yield suppression of Poa. We also have found that 200 GDD applications to mixed bent/*Poa* green decreased the *Poa annua* population from 23% to 16% of the surface.

The GDD threshold for *NYTrimmit application to creeping bentgrass and *Poa annua* golf putting greens is 300 GDD re-applications (base °C) maintained yield suppression during the growing season for both grass species. After approximately 350 GDD the turf entered the rebound phase. Use these new models to determine best application frequency for PGR use.

Table 4.4.1 – Plant Growth Regulators labeled for Annual bluegrass seedhead suppression

Active Ingredient (Trade Name)	Product Rate/ Application Timing	REI[1] (Hours)	Field Use EIQ[2]	Comments
paclobutrazol, flurprimidol, trinexapac-ethyl (Musketeer)	.28-.92 fl oz/1000 sq ft	-	2.7 – 8.9	Do not use on residential turf. Not for use on sod farms, in seed production, or for research.
*NY trinexapac-ethyl (Primo Maxx)	.125-.25 fl oz/1000 sq ft	0	3.5 – 5.9	The REI is 0 as long as footwear is used. Otherwise, the REI is until the spray has dried. For improved seedhead suppression, tank mix with *NYProxy. Do not exceed a total of 7 fl oz/1000 sq ft/year. For annual bluegrass suppression in creeping bentgrass, use highest rate and expect some discoloration. Best conversion achieved in association with overseeding program.

[1] REI = Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2] Field Use EIQ = A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ.

Table 4.4.2 – Plant Growth Regulators labeled for Mowing management

Active Ingredient (Trade Name)	Product Rate/ Application Timing	REI[1] (Hours)	Field Use EIQ[2]	Comments
*NY ethephon (Proxy)	5 fl oz/1000 sq ft	--	73.3	For mowing management, combine with trinexapac, avoid thatchy areas, and make no more than six applications.
mefluidide (Embark 2-S)	0.6 fl oz/1000 sq ft	--	3.7	Not for use on turf being grown for sod or commercial seed production. Do not apply to golf greens. See label for maximum rates/year and timing. For mowing management, use lowest labeled rate for Kentucky bluegrass.
mefluidide Embark T & O)	1.8 fl oz/1000 sq ft	--	1.3	Not for use on turf being grown for sod or commercial seed production. See label for maximum rates/year and timing. For mowing management, use lowest labeled rate for Kentucky bluegrass.
*NY paclobutrazol (Clarelle)	6.4-32 oz/acre	12	2.4 – 12.1	Do not use on residential turf. For mowing management, apply after first or second mowing and one month before high temperature or frost.
paclobutrazol, flurprimidol, trinexapac-ethyl (Musketeer)	.28-.92 fl oz/1000 sq ft	-	2.7 – 8.9	Do not use on residential turf. Not for use on sod farms, in seed production, or for research.

*NY paclobutrazol (Trimmit)	16-32 oz/acre	12	6.1 – 12.1	Do not use on residential turf. For mowing management, apply after first or second mowing and one month before high temperature or frost.
prohexadione calcium (Anuew)	.05-.27 oz/1000 sq ft	12	.3 – 2.4	Do not apply to grass grown for seed. Suggest application interval every 280-350 base 32 growing degree days.
trinexapac-ethyl, flurprimidol (Edgeless)	.69-1.83 fl oz/1000 sq ft	-	9.7 – 25.7	Not for use on sod farms, in seed production, or for research.
*NY trinexapac-ethyl (Governor)	5.2 lbs/1000 sq ft	-	6.5	
*NY trinexapac-ethyl (Primo Maxx)	0.125-1.0 fl oz/1000 sq ft	0	3.5 – 5.9	The REI is 0 as long as footwear is used. Otherwise, the REI is until the spray has dried. Do not exceed a total of 7 fl oz/1000 sq ft/year. For mowing management, apply when turf is actively growing and expect 50 percent growth reduction for 4 weeks with minimal yellowing.

[1] REI = Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2] Field Use EIQ = A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ.
*NY - Restricted-use pesticide in New York State.

Table 4.4.3 – Plant Growth Regulators labeled for Seedhead suppression

Active Ingredient (Trade Name)	Product Rate/ Application Timing	REI[1] (Hours)	Field Use EIQ[2]	Comments
mefluidide 2-S (Embark)	0.6 fl oz/1000 sq ft	--	3.7	Not for use on turf being grown for sod or commercial seed production. Do not apply to golf greens. See label for maximum rates/year and timing. For ideal seedhead suppression, time application between 500-650 base 32 growing degree days. Tank mix with trinexapac to prolong suppression and minimize stress induced disease.
mefluidide Embark T & O)	1.8 fl oz/1000 sq ft	--	1.3	See label for maximum rates/year and timing.
*NY ethephon (Proxy)	5 fl oz/1000 sq ft	--	73.3	Poa annua and white clover seedhead suppression only. Reapplication interval: 2 weeks or greater. For ideal seedhead suppression, time application between 400-600 base 32 growing degree days. Tank mix with trinexapac to prolong suppression and minimize stress induced disease.

[1] REI = Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2] Field Use EIQ = A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ.
*NY - Restricted-use pesticide in New York State.

5 Disease Management

5.1 Diagnosis of Turfgrass Diseases

Diseases are perhaps the most unusual and perplexing of the important pest problems affecting highly managed turf. As a result, diagnosing problems that may be caused by disease represents one of the more challenging exercises in turfgrass management.

Both weed and insect pests can be readily observed with the unaided eye. And insects or weeds, regardless of their stage of development, look much the same regardless of the environment in which they are found. Further, being readily visible, their appearance can be matched with the diagrams and photographs presented in diagnostic references.

Diseases, on the other hand, are caused by a wide variety of microscopic organisms, none of which are observable without the aid of a microscope. Further, the activities of these pathogens can be seen only indirectly, by observing the responses of the turfgrass plants they have infected. Diagnosis is further complicated by the fact that the symptoms of infection by a particular pathogen may differ, depending on factors such as the species of grass infected, the height of cut, local environmental conditions, or the presence of other pests and pathogens. Among the more important factors affecting the expression of symptoms is the presence of chemical, physical, and biological stresses.

Disease diagnosis can be thought of as a process of elimination, in which the range of potential causes for the observed problem is carefully reduced to one. The sequence of steps one follows in diagnosing turfgrass diseases is designed to assemble evidence for and against possible causes for the observed problem. It is important, therefore, that turfgrass managers maintain accurate and complete records of both site management activities and the season's weather. When these two data sets are combined with careful observations of the turfgrass symptoms and direct observations of pathogen structures, establishment of associations between the disease and a causal agent is possible.

Turfgrasses, because they are perennial plants, develop long-term associations with pathogens. In fact, in nearly all mature turfgrass plantings, individual plants are perennially infected with many, if not all, of the pathogens capable of causing disease on that particular grass species. This is the reason that symptoms of many turfgrass diseases are observed most frequently when turfgrass plants are under stress. It also further complicates disease diagnosis, since the presence of many turfgrass pathogens in a given sample makes reducing the probable causes of the symptoms observed to a single causative agent difficult.

Because of all of these difficulties, competent disease diagnosis requires considerable training and experience. Turfgrass managers often turn to academic experts to assist in the diagnostic process, coupling their expertise in the field with the academic's expertise in the diagnostic laboratory to establish the cause of the problem and to recommend and carry out appropriate control measures.

5.1.1 Importance of Correct Disease Diagnosis

Proper diagnosis is central to any successful turfgrass disease management program. There are a number of reasons for this. First, identifying the cause of any disease problem helps the turfgrass manager identify some of the conditions that may have fostered its development. In a sense, the diagnosis itself helps the turfgrass manager learn something about the biology of the causal agents, and how to limit their impact.

Second, many contemporary disease control strategies are quite specific, being effective against one disease, ineffective against others, and potentially making still other diseases much worse. For example, the mode of action of fungicides can be very narrow, affecting only certain groups of fungal pathogens. Inaccurate diagnoses could thus lead to the application of unneeded fungicides, the side effects of which could be damaging.

Third, the refinement of Integrated Pest Management (IPM) scouting and monitoring protocols to fit the situation at hand is dependent on accurate identification of turfgrass pest problems. This is easily accomplished for weed and insect pests, but has been problematic for diseases. Accurate diagnosis gives turfgrass managers the ability to map and measure specific disease problems so that more effective control strategies can be implemented. It also gives them the ability to establish the efficacy of control measures and assists in the prediction of future disease outbreaks.

5.1.2 Basic Analytical Processes in Disease Diagnosis

All disease diagnostic procedures follow a logical sequence of steps, designed to gather evidence sufficient for the elimination from consideration of potential causal agents. Both field and laboratory observations are used in assembling this information.

One of the first challenges to any turfgrass manager is to determine whether an observed problem is actually the result of a disease. Disease symptoms often appear remarkably similar to damage from noninfectious agents (insects, for instance) or from a variety of abiotic problems (such as localized dry spots). Sometimes, the characteristics of the damage can provide clues. The patch-like appearance of symptoms, usually more apparent on close-cut than on higher-cut turf, may be indicative of a disease problem.

Most known turfgrass diseases are caused by fungi. Since fungi tend to grow radially, many fungal pathogens cause circular patch-like symptoms in turfgrass plantings. There are several turfgrasses diseases, however, that do not typically induce patch symptoms, and these are commonly confused with signs of other turfgrass problems. The following are the steps one usually would go through in diagnosing these and other turfgrass diseases.

STEP 1. Identification of Affected Grass Species and Cultivars

One of the first steps in any diagnosis is to determine specifically which plants are affected. A number of turfgrass pathogens are relatively specific to particular turfgrass species, some even to individual turfgrass cultivars within a species. Take-all patch, for example, caused by *Gaeumannomyces graminis* var. *avenae* is generally found only on creeping bentgrass varieties, and not on other turfgrass species. Similarly, summer patch disease caused by *Magnaporthe poae* is found on bluegrasses and fine fescues, but rarely, if ever, on perennial ryegrass varieties. Even within a turfgrass species, cultivars can vary in response to diseases. For example, varieties of Kentucky bluegrass such as Bristol, Eclipse, and Glade are relatively tolerant of summer patch disease, while varieties such as Chateau and Fylking are quite susceptible.

On golf courses where mixed stands of annual bluegrass and varieties of creeping bentgrass are quite common, it is frequently observed that the annual bluegrass is affected more severely, or shows symptoms much earlier, than the creeping bentgrass variety. This is sometimes true for root and crown diseases such as Pythium root rot caused by *Pythium graminicola*, anthracnose caused by *Colletotrichum graminicola*, and some nematode problems.

STEP 2. Observation of the Entire Affected Area for Symptoms

Where symptoms are located in the affected area, and how they appear, can reveal important information about the distribution of the disease and the types of pathogens usually found associated with that distribution pattern. For example, it is useful to know whether symptoms are restricted to wet, low lying areas, or to high, dry areas. It would also be noteworthy if symptoms were limited to areas of intense foot or equipment traffic, or to areas of extreme soil compaction. Equally important factors affecting symptom distribution are soil factors such as texture and pH as well as the degree of shade and the proximity of structures such as buildings, roads, and sidewalks that may alter soil temperatures.

The appearance of the symptoms is equally important. For example, it is important to note whether the symptoms appear randomly and without discernible structure throughout the affected area, or whether they are localized in patch- or ring-like patterns. A number of turfgrass diseases usually appear as rings or patches, and only rarely diffused throughout susceptible turfgrasses. Root and crown diseases generally give rise to more patch– or ring–like symptoms; foliar diseases tend to result in more diffuse symptoms. In some cases, disease symptoms that appear patch-like on close-cut turf may seem diffuse on higher-cut turf. On the other hand, foliar diseases such as dollar spot and red thread may actually appear patch-like on both high-cut and close-cut turf.

Examining the overall complex of symptoms at this stage of the diagnostic process will help to sort out whether what is being observed is a biotic or abiotic problem. For example, if symptoms appear in a highly regular pattern, this may be indicative of a problem caused by maintenance equipment. For example, misapplication of fertilizers or pesticides, or the movement of equipment over heat-stressed turf may appear in regular patterns. Examining turf at this stage may also reveal the presence of other noninfectious biotic factors such as insects, algae, or moss that may be contributing to the observed problem.

Often, when assessing overall symptoms, it is difficult to determine whether the problem under examination is currently active and worsening or has been inactive for some time. This is particularly true of diseases such as red thread, caused by *Laetisaria fuciformis*. On perennial ryegrasses and fine-leafed fescues, necrotic patches from red thread damage are frequently apparent long after the pathogen has ceased to be active. Generally, the only way to tell this is to get down on one's hands and knees and examine turfgrass plants closely for the presence of progressive symptoms and/or the presence of pathogen structures. For foliar diseases, the mycelium or other structures are sometimes visible when the pathogen is active or has recently been active. For root diseases, fungal activity cannot be easily assessed.

STEP 3. Observation of the Specific Plant Symptoms

Specific symptoms on individual plants generally provide much more information on the possible cause of disease problems, and can be one of the most important diagnostic features available for some diseases. The principal above-ground symptoms to look for at this stage are leaf spots, paying particular attention to the appearance of the lesions. For example, it's important to determine whether the lesions are irregular in shape or circular, whether they are bordered with a yellow (i.e. chlorotic) halo or by a purplish or brownish area. Blighting is another frequently observed above-ground symptom in which the plant, particularly the leaves, turns brown (i.e. necrotic). With leaves, for example, it is important to note whether they appear to be blighting from the tip down, or from the basal stem upward. Other commonly observed above-ground symptoms include wilting, stunting, and rotting. More specific observations about these symptoms would include such things as whether, during wilting or rotting, the plants appear to be dry, or are wet and greasy in appearance.

In addition to the appearance of specific plant symptoms, it is important to note the individual plant parts affected. Blighting symptoms may appear on leaves or sheaths, for example. Rots may appear on sheaths, roots, and rhizomes. Rotting symptoms are most frequently observed on below-ground plant parts.

Root and Crown Diseases Present Special Problems
Root and crown diseases are challenging diagnostic problems. These challenges arise from a number of factors. One of the greatest obstacles to the accurate diagnosis of root and crown diseases is the perennial nature of turfgrass plants. Roots of nearly all mature turfgrass plants are continuously infected with many, if not all, of the pathogens capable of causing disease on a particular turfgrass species. As a result, microscopic examination of roots and crowns usually fails to identify a single pathogen as the cause of an affliction.

Another complicating factor is the presence of a large number of saprophytic fungi, which prefer to live on dead and decaying organic matter. Few of these fungi cause infection or disease in turfgrass plants, but they are readily observed on and in roots, rhizomes, stolons, and crowns. Some of them may even penetrate the roots of some turfgrasses, but they rarely, if ever, cause direct plant damage.

The natural senescence of many turfgrass roots also presents diagnostic challenges. Roots of turfgrasses naturally age and wither at a rapid rate. In the process, they are often colonized by a vast array of microorganisms, both pathogenic and non-pathogenic. Since many of the pathogens causing root and crown problems prefer to live in a saprophytic mode, it is often not clear, when examining roots microscopically, whether a pathogen found to be present in the root was the cause of its decline, or colonized the root tissues after that decline had already set in. This dilemma is further complicated by the fact that, when examining roots microscopically, one can never be certain if the roots showing symptoms are the current year's or from the previous season, and if the previous year's roots, whether their decline was natural or disease induced.

One of the more aggravating problems in diagnosing root diseases is the difficulty in completing Koch's postulates satisfactorily. For the most part, the ability of root infecting pathogens to cause significant levels of disease depends heavily on environmental conditions and plant stresses. Turfgrass plants that are not under significant stress often fail to show foliar or root disease symptoms after infection of their roots. However, plants that are heavily stressed by excessively low mowing heights, excessively low or high fertilization regimes, excessively low or high soil moisture, excessive temperatures, high traffic, soil compaction, and certain pesticide applications are more likely to decline as a result of root infection. In addition, those pathogens infecting root tips, root hairs, or the epidermal layers of the root may not cause any significant necrosis, but may debilitate nutrient and water uptake through the root system. These types of pathogens may be particularly difficult to isolate from turfgrass roots, making it impossible to link them to the observed disease.

A critical aspect of the diagnosis of root diseases is the proper sampling and recovery of the root system from soil, so that thorough examination will be possible. Roots are typically covered with soil and other organic debris. They may also be difficult to free from thatch. All of these factors make root observations difficult.

When turfgrass managers examine the root systems of plants, a clump of turf is frequently ripped from the ground, teased apart to some degree, and examined in a way that can create artifacts. First, when roots are infected with pathogens, the root tissues often become fragile and easily subject to breakage. By ripping up a clump of turf, many of the diseased turfgrass roots are left behind in the soil, leaving healthy roots attached to the shoots. With just a casual inspection of such a sample, one might conclude that the roots were healthy, when in fact they might be seriously diseased. Second, soil and thatch in the specimen can make suitable observations of roots nearly impossible. A more effective method of removing roots from soil is to cut a section of affected sod with a knife to a depth of approximately 2 inches, then place the turfgrass specimen under a stream of water while gently pulling the specimen apart. The goal of this manipulation is to tease out individual plants with root systems intact and free of interfering thatch and soil debris. If special care is taken at this stage, an accurate diagnosis will be possible.

Just to complicate matters, it should be noted that numerous abiotic factors also contribute to root dysfunction and decline. Of particular importance here are high concentrations of soluble salts, root zone oxygen depletion, and excessive soil temperatures. The natural senescence of turfgrass roots, particularly during the summer months, further complicates the picture. These factors must always be taken into account when contemplating, or conducting, root disease diagnosis, and examined critically as part of any routine diagnostic procedure.

STEP 4. Field Observations of Pathogen Structures in Turfgrass Tissues

Since most fungi are identifiable by their characteristic reproductive structures, one of the more definitive pieces of evidence linking a specific pathogen to the cause of a disease problem is the presence of such structures. These are observed best in the laboratory, but they can be seen frequently on infected tissues in the field. The use of a 10X hand lens or other magnification device is a requisite for the identification of pathogen structures in the field. A good example of a disease for which diagnostic reproductive structures may be seen under low magnification is anthracnose, caused by *Colletotrichum gramincola*.

During disease development some pathogens produce structures that do not require magnification in order to be seen. For example, *Laetisaria fuciformis*, the cause of red thread, produces characteristic pink to red thread-like structures which are readily visible and diagnostic. The same is true of pathogens such as *Typhula incarnata*, the cause of Typhula blight, and *Erisyphe graminis*, the cause of powdery mildew. Without a doubt, the observation and identification of pathogen structures associated with turfgrass plants can advance the diagnostic process significantly, since this information not only allows the identification of the pathogen, but, as they tend to be short-lived, the presence of reproductive structures is an indication that the pathogen is or has recently been active.

Observation of Root Systems

Once individual plants are obtained with an intact root system, it is relatively easy to determine whether their roots show any disease symptoms. It may be useful to examine roots of apparently healthy turfgrass plants for comparison. Things to look for (and record) are:

1. The absence of root hairs.
2. Discolorations of the root system, particularly at the root tips.
3. Any noticeable lesions or other deformities and their specific appearance.
4. The condition of the crown area.
5. Whether discolorations or rotting appear to be progressing from the crown to the roots or from the roots to the crown.
6. Any visible fungal structures on or in the root and crown area (this usually requires a 10X or better hand lens).
7. The nature of the rotting on the root system. For example, do the roots exhibit a wet, gooey rot or a dry rot? The former is more characteristic of pathogens such as *Pythium* species while the latter is more representative of other patch disease root pathogens such as *Magnaporthe* and *Leptosphaeria*.
8. The presence of dark fungal mycelium growing on the surfaces of root and crown tissues.

These structures are often observable with a 10X hand lens or a dissecting microscope and are indicative of problems associated with patch diseases.

STEP 5. Recording the Cultural and Environmental Conditions

Recording the cultural conditions prior to and during the onset of disease symptoms is an important part of the evidence gathering process, and can be critical in making an accurate diagnosis. The same is true of the environmental and climatological conditions immediately preceding the onset of symptoms, which can quickly eliminate certain possible pathogens from consideration as potential causal agents.

Some of the important cultural conditions to record include: the age of the turfgrass planting, the specific fertilization, irrigation, and pest control practices employed, including materials and amounts applied. Grooming or growth management practices should be noted as well; so should any peculiarities such as increased traffic, excessive thatch, unusual soil odors, and the like. If appropriate, unusual features of the landscape such as the presence of large trees or roots in and around the affected site, shading, air and water drainage, and soil pH should also be noted.

The important climatological information to record would include maximum and minimum daily temperatures, relative humidity, rainfall, cloud cover and wind speed. Obviously, the most appropriate weather data would be those collected on the affected site. National Weather Service data may also be useful; however, if a recording station is located sufficiently near the site.

STEP 6. Attempting an Initial Diagnosis

At this stage, once all the pertinent field information has been gathered, a tentative diagnosis may be attempted. Numerous diagnostic guides have been written to aid in the diagnosis of turfgrass diseases. Disease identification manuals may be available from the state's land grant universities. Similar manuals may be available from pesticide and fertilizer manufacturers, the federal government, private consultants, professional turfgrass associations, and scientific societies. There are, in addition, number of textbooks devoted exclusively to turfgrass diseases. If no clear diagnosis can be made after making the observations, examining the cultural and environmental data, and consulting the manuals, then the next step in the process is to enlist the help of a competent laboratory diagnostician.

Root Diseases Should be Left to a Clinical Diagnostician

In nearly all cases, definitive diagnosis of root diseases requires a microscopic examination. This is necessary to actually observe the presence of the pathogen in infected and rotting roots and crowns. To accomplish this, small sections of symptomatic root, crown, rhizome, or stolon tissue are placed on a microscope slide and stained with chemicals designed to color the pathogen and not the plant tissues. In some cases, diagnosticians may use other chemicals to remove the contents of root cells, making observations of fungal structures in root tissues easier.

Occasionally, obvious pathogen structures are not apparent. In these cases, the laboratory diagnostician may attempt to isolate and culture the pathogens from root or crown tissues. This is usually accomplished by placing pieces of fresh root tissues on sterile synthetic culture media that foster the growth of microorganisms. Sometimes, if a specific group of pathogens is suspected, turfgrass roots may be placed on media containing chemicals that will only allow that group of organisms to grow. If pathogens are present, they will usually emerge from the infected roots and grow on the culture medium, facilitating a more detailed study of the organism. Once potential pathogens are recovered from infected roots, attempts can be made to complete Koch's postulates.

Most of the techniques used to diagnose root and crown diseases require specialized equipment and considerable expertise. **Even experienced turfgrass pathologists have difficulties diagnosing some root and crown diseases on turfgrasses**. As we learn more about the biology of root infecting turfgrass pathogens, however, and as more sophisticated techniques for their detection and identification are developed, root disease diagnosis will become more accurate.

STEP 7. Collecting and Submitting Samples for Clinical Diagnosis

In order to insure that the laboratory diagnostician has all the information required to make an accurate diagnosis, it is important that a proper sample be collected and that it be sent along with the appropriate field observations. Turfgrass samples with apparent above-ground or below-ground symptoms should be collected as the problem appears to be on the increase, preferably during the early stages of disease onset. Samples collected long after the problem was first observed are usually difficult to diagnose accurately. The samples collected should be representative of the symptoms observed over the entire affected area. Since the clinical diagnostician does not have the luxury of observing the problem first hand in the field, it is critical that the sample is accompanied by an adequate description of the problem, a record of the cultural practices, and a description of the environmental and climatological conditions that were present at the time the problem was first observed.

Critical information to include with the sample would be the following:

1. The grass species. If known, the precise cultivars.
2. A description of the overall symptoms, the date they first appeared, and the extent of the affected area. Be specific about symptom location and appearance.
3. A description of the cultural conditions prior to and during the onset of symptoms.
4. A description of the climatological conditions prior to and during the onset of symptoms.
5. A digital photograph of the affected area.

To facilitate comparison in the laboratory, it is ideal to collect a sample from apparently healthy turf as well as from the turf showing symptoms. However, samples should not be collected shortly after a fungicide application is made. Generally, if the fungicide is effective against the suspected pathogen, it will have done its work prior to the sample being analyzed, making it impossible to obtain a meaningful diagnosis.

If symptoms are patch-like, sample from the edge of the patch, being sure to obtain both healthy and diseased turf in the sample. This allows the diagnostician to watch the disease progress in the laboratory. If symptoms are diffuse, take two samples: one from the diseased area and one from an adjacent apparently healthy area. Even though many turfgrass pathogens are readily apparent in both healthy and diseased turf, having both helps eliminate some pathogens as the primary disease causing agents since the relative abundance of a causal agent may be greater in a diseased than in a healthy turfgrass specimen. Turf collected from golf courses may be sampled with a cup cutter and need only be removed to a depth of two to three inches. If you do not plan to sample with a cup cutter, use a knife and cut a 6" X 6" piece of sod no more than two inches deep. Be sure to sample from both symptomatic and apparently healthy areas as described above.

Proper packaging of the sample for shipment to a diagnostic laboratory is critical. If the sample is relatively moist, wrap it in newspaper or aluminum foil, and place it in a cardboard box for mailing. If the sample is dry, moisten it slightly, wrap, pack, and mail as described above. Avoid wrapping samples in plastic or placing in plastic bags since these materials retain moisture in the sample and encourage many different organisms to grow, possibly masking important symptoms. Avoid exposure to heat or direct sunlight.

If a nematode problem is suspected, it is best to sample from both healthy and symptomatic areas. The most appropriate times to obtain such samples are in the spring, about a month after the turf greens up, and in the autumn, when turf may be more symptomatic. Sampling patterns depend on the symptoms present and the size of the affected area. If the turf is exhibiting a gradual decline, samples should be taken randomly throughout the area (in a zigzag pattern, for example). A minimum of six subsamples should be taken from an area that is 1/2 acre (~21,000 sq. ft.) in size. If symptoms appear in patches, subsamples should be taken just inside the periphery of the patch. All samples should be taken to a depth of approximately four inches. Subsamples may be taken with a cup cutter, a 1-inch soil sampling probe, or a trowel. Subsamples should be mixed together, placed in a plastic bag and shipped immediately. Avoid exposure to heat or direct sunlight. It is best NOT to moisten samples.

It is always best to collect and mail turfgrass samples early in the week, so they do not spend the weekend in a post office or at the diagnostic laboratory. It is always helpful to telephone the diagnostic lab before sending the sample to make sure that the diagnostician is prepared to receive and process the sample quickly. This is particularly important during the busiest months of the season (June, July, and

August). Whenever possible, samples should be sent to the diagnostic laboratory using an overnight delivery service.

In New York State, to submit samples for disease diagnosis, contact Plant Disease Clinic, Cornell University, Department of Plant Pathology, 334 Plant Science Building, Ithaca, NY 14853-4203, (607) 255-7850, plantclinic.cornell.edu.

STEP 8. Laboratory Examination of Turfgrass Samples

The close examination of turfgrass samples, whether in the field or in the laboratory, is a critical part of nearly all disease diagnoses. First, it serves as a means of verifying initial diagnoses based on field observations, and provides the turfgrass manager with a means of relating known causal agents and diseases to specific above- ground symptoms. Second, in the case of some diseases, it provides the only means of definitively identifying the cause of the problem. The purpose of this close laboratory examination is to find physical evidence for the presence of the causal agent(s). Nearly all fungi causing diseases in turfgrasses produce characteristic structures, reproductive as well as non-reproductive, in affected plants. Since nearly all of the fungal structures are microscopic, and therefore not visible without magnification, the clinical diagnostician depends heavily on the use of the microscope for these important observations. Generally, two types of microscopes are used in the examination of turfgrass specimens: a dissecting microscope for examining whole plants and plant organs, and a compound microscope for observing tissues and cells. Observation and classification of the fungal reproductive structures allows the diagnostician to more accurately identify the active pathogens. The structures for which diagnosticians look include: characteristic spore shapes, sizes, and colors, unique mycelial shapes and structures, sclerotia, and fruiting bodies such as pycnidia, acervuli, and perithecia. The diagnostician must also check for the presence of other causal agents such as bacteria, viruses, algae, and nematodes.

In some cases, no fungal structures may be apparent when tissues are observed under the microscope. In this case, leaf, sheath, or crown tissues may be incubated in a high humidity chamber to encourage whatever fungal pathogens may be present to grow in a mycelial form or to sporulate, thus revealing its reproductive structures for identification. These fungal tissues may then be transferred to laboratory culture media for further observation, or examined under the compound microscope. However, since many different microbes on or in affected turfgrass tissues can grow and reproduce in this environment, the diagnostician may find evidence of several different fungal pathogens, along with a myriad of nonpathogenic or saprophytic fungi and other microorganisms.

If physical evidence of a pathogen cannot be found in turfgrass tissue, other methods for the detection and identification of pathogens may be used. The most common back-up method for pathogen detection and visualization is the isolation of the potential pathogen from the turfgrass tissue. Most fungal turfgrass pathogens can be readily grown on laboratory culture media. However, a few turfgrass pathogens are obligate parasites and are consequently not readily culturable. The latter include *Puccinia* and *Uromyces* spp., causing rust diseases, *Erisyphe graminis* causing powdery mildew, and *Sclerophthora macrospora* causing yellow tuft disease. Once a pathogen has been cultured successfully in the laboratory, its growth and reproductive habits can be observed more closely and its physical appearance compared with what was observed in the diseased tissue.

Over the past few years, even more sophisticated methods of pathogen detection have been developed. These include immunological techniques using pathogen specific antibodies to detect the present of specific pathogens in turfgrass tissues. More recent developments include methods for the analysis of pathogen DNA in the host tissue. These are similar to the blood DNA analysis currently used in courtroom murder trials. Such techniques provide some of the most sensitive and accurate methods available for identifying particular pathogens, and may prove to be the only means of confirming that the suspected pathogen is, in fact, the primary disease causing agent.

In the event no evidence of fungal pathogens can be found, the obvious conclusion is that the problem is either not a result of disease, or, if it is a disease, it can only be the product of a non-fungal pathogen. Other likely causal agents include viruses, bacteria, and nematodes. The problem could also be caused by noninfectious biotic agents such as algae, mosses, insects, or rodents, or by abiotic agents.

STEP 9. Making the Final Diagnosis: Pulling it all Together

Once all the pertinent information from field and laboratory has been assembled, the clinician faces the difficult task of interpreting all of the evidence and coming up with an accurate diagnosis. It should be noted that, while the process of assembling diagnostic evidence is rigorous, interpreting that evidence and making the diagnosis is more art than science. Making the actual diagnosis constitutes the greatest part of the educated guessing that goes on in this process.

Sometimes the evidence accumulated is either incomplete or inconclusive. In this case, further field observations, followed by another round of clinical examinations, may be warranted. In most cases, however, a diagnosis will prove possible.

Particularly in difficult cases, the results of the laboratory examination of the sample will be the pivotal evidence on which the diagnosis is based. As is frequently the case, however, the clinical diagnostician may find evidence of two or more pathogens in the diseased specimen. Here is where the cultural and environmental information accompanying the sample becomes critical and must be evaluated together with the clinical observations to further narrow the range of possible causes. A diagnostician's ability to make accurate diagnoses is based primarily on his or her knowledge of specific diseases, the factors affecting their causal agents, and the pathogens themselves. Numerous written resources, in addition to those noted previously, are available to aid the diagnostician in retrieving this important information and making accurate diagnoses.

Diagnoses may be reported to the turfgrass manager in a variety of ways. Most commonly, a written report, identifying the pathogen(s) believed to be the primary cause(s) of disease(s), is sent directly to the person submitting the sample. Often, to permit timely steps to control a problem, diagnoses will also be made by telephone, prior to the submission of a written report. Prices for diagnostic services vary, but are generally in the range of $25 to $75, depending on the laboratory and the detail of the diagnosis.

STEP 10: Selection of an Appropriate Management Strategy

Recommendations are likely to accompany the diagnosis. It is up to the turfgrass manager, however, to select appropriate management strategies and implement them properly.

5.2 Maximizing the Use of Fungicides for Disease Control

5.2.1 Fungicide Use and General Properties

The application of fungicides has historically been the major tactic for controlling diseases on high quality turfgrasses. In many cases, without the application of fungicides, golf course turfgrass management practices would not be what they are today. For example, the trends toward lower cutting heights, the ever-increasing amount of traffic on putting greens, and the low nutrient inputs to maintain high performance characteristics, have placed unprecedented stresses on turfgrass plants, making them highly susceptible to damage from many different diseases, some of which were previously considered relatively unimportant.

Because turfgrass plants in general, and golf course putting greens in particular, are growing under less than ideal conditions, the level of disease control typically achieved with fungicides is less than desirable. In fact, nearly all disease control strategies are less than desirable on overly compromised turf.

Effective disease management requires an understanding of some basic concepts of turfgrass fungicides and how they work in controlling turfgrass diseases. In addition, it is vital to know soil, plant, pathogen, and environmental factors that affect fungicide efficacy and considerations to keep in mind with application equipment, application strategies, and record-keeping to enhance disease control with fungicides.

5.2.2 Fungicide Labels

One of the more overwhelming aspects of using and applying fungicides is the information on the fungicide label. Being quite familiar with this information is not only a legal responsibility, but it will help you as an applicator to make more effective applications and reduce detrimental environmental and health related side effects of improper applications. The label serves several purposes: 1) to identify the chemicals involved, 2) to identify the uses for which the product is registered, 3) to describe the recommended dosages for specific disease problems, and 4) to identify any potential human and environmental hazards, and any incompatibilities or phytotoxicities. The label consists of the printed material on, attached to, or accompanying the fungicide container and should be read thoroughly before use.

The most obvious part of any fungicide label is the trade name of the fungicide. This is the name the manufacturer assigns to the product. It has little to do with the actual chemical ingredients in the container. For any given fungicidal compound, there may be many different trade names, depending on the target crops and the company manufacturing the particular formulation. Other more obvious parts of the fungicide label include the chemical name of the active ingredients, the formulation, signal words indicating the relative human toxicity, and general information on use, reentry, storage, disposal and safety.

One of the more apparently trivial but perhaps one of the more important parts of the fungicide label is the Environmental Protection Agency (EPA) registration number. The fact that the number is on the label signifies that this material is indeed a pesticide, and not a product intended for any other use. Every registered pesticide has an EPA registration number and its presence on the label represents that the EPA has reviewed information about the product and that the product will do what the manufacturers claim it will do. There are a number of products on the market that make claims about disease control. However, only those that carry an EPA registration number can be used legally for the control of specific turfgrass diseases.

Labels should be consulted before purchasing, mixing and applying turfgrass fungicides. For example, you should read the label to fully understand what protective equipment to use and the compatibility of the fungicide with other pesticides, adjuvants, growth regulators, and fertilizer. Often on turfgrass fungicide labels, two different application rates will be listed: a preventive rate and a curative rate. Based on the label rates used, the total amount of fungicide to be applied should be accurately calculated and the proper mixing and safety procedures followed.

5.2.3 Fungicide Formulations

Turfgrass fungicides are never sold with simply the active fungicidal compound. They are always mixed with other so-called inert ingredients to make them easier to handle, apply, and store (Table 5.2.1). On all fungicide labels are listed the percentage of the formulation that is composed of the active ingredient and inert ingredients. In nearly every case, the inert ingredients make up the largest part of the fungicide formulation. Unfortunately, the inert ingredients are rarely specified on the label. Keep in mind that inert ingredients can pose hazards as well, particularly those in emulsifiable concentrate formulations where the inert ingredients are petroleum-based solvents such as benzene, naphthalene, and xylene. Many new pesticide formulations have eliminated the use of petroleum based solvents.

Table 5.2.1. Formulations of turfgrass fungicides

Abbreviation	Type of Formulation
AS	Aqueous solution
DF	Dry flowable
E or EC	Emulsifiable concentrate
F or FLO	Flowable
G	Granular
MEC	Microencapsulated Concentrate
SC	Soluble concentrate
W or WP	Wettable powder
WDG, WG	Water dispersible granule
WSP	Water soluble packet

Historically, the most common types of formulations for turfgrass fungicides have been granular and wettable powder formulations. These are dry formulations in which the fungicidal compound is placed on particles or granules of clay or other types of dried plant material. Granular materials have the advantage of being applied in a dry form. Wettable powder formulations need to be mixed with water where they form a suspension that can be sprayed.

Whereas the ability to make spray applications is a positive attribute of wettable powder formulations, the main negative aspect of their use centers around the generation of considerable amounts of dust during weighing and mixing operations. Wettable powders can be difficult to handle and so manufacturers have developed water dispersible granules (or dry flowables), flowables, and water soluble packets. In addition to reducing handling problem, these formulations also allow for more accurate measuring. Regardless of whether a wettable powder, flowables, water dispersible granules or water soluble packets are used, the fungicide formulation is such that it forms a suspension in water and not a solution. The material, therefore, must be constantly agitated in the spray tank to avoid settling of the suspended particles and care must be taken to keep spray nozzles unclogged.

Among the more common formulations of many of the newer fungicides are emulsifiable concentrates. These formulations consist of the active fungicidal ingredient dissolved in a solvent that, when mixed with and agitated in water, forms an emulsion. Furthermore, these formulations also avoid the problems with dust generation and nozzle clogging. Unlike the wettable powders, flowables, and water soluble packets, for which the active ingredients are specified as a percentage of the total formulation, the active ingredient in emulsifiable concentrates is expressed as pounds of active ingredient per gallon of formulation.

The type of formulation used may affect the overall efficacy of the fungicide. In particular, granular formulations seem to be less effective, as a general rule, than other sprayable fungicide with the same active ingredient. For example, granular formulations of contact and localized penetrant fungicide used for the control of foliar diseases of turfgrasses may require substantially more applied active ingredient than a spray application to achieve the same level of disease control. Generally, the systemic penetrant fungicides are more effective than the contact fungicides when formulated as a granular product. On the other hand, when applied for the control of root and crown diseases, granular formulations can be quite effective, providing a slow release of fungicide right at the crown area.

5.2.4 Types of Turfgrass Fungicides

Fungicides used for turfgrass disease control can be categorized either as contact or penetrant fungicides. Many of the older products consisted primarily of contact fungicides. Examples of these include anilazine, chlorothalonil, etridiazole, mancozeb, quintozene, and thiram. Contact fungicides are typically applied to foliage to prevent pathogenic fungi from infecting foliar tissues. However, these fungicides are also effective in killing pathogens in the root and crown area as long as the fungicide can be delivered properly to that area.

Contact fungicides are generally capable of killing both dormant spores and dormant and active mycelium of pathogenic fungi. However, they must be reapplied frequently so that newly formed grass tissues remain protected. In order for contact fungicides to be effective foliar protectants, they must be allowed to dry on the plant surface after application. Therefore, in order to achieve the most effective control of foliar diseases with contact fungicides, they should never be watered-in or applied in the rain. If, on the other hand, they are to be used to control pathogen activity in thatch or in the root zone, they should be watered-in. More specific aspects of post-application treatments will be covered later.

The majority of fungicides used today for turfgrass disease control are penetrant fungicides. This means that they are absorbed to varying degrees by the plant tissues to which they are applied. For systemic penetrant fungicides, they can move in the plant vascular system from the original site of application to other distant plant parts. Most of the currently used systemic penetrant fungicides are translocated upward in the plant. These would include all of the sterol inhibiting and benzimidazole fungicides (Table 5.2.2), as well as mefenoxam and flutolanil. A few turfgrass fungicides have only limited movement away from the site of plant uptake. These would include the dicarboximide fungicides iprodione and vinclozolin and the carbamate fungicide propamocarb. Only one turfgrass fungicide, fosetyl-al, has significant downward movement.

Table 5.2.2 Movement of turfgrass fungicides in plants

Movement Type	Fungicide
Contacts	
(No Internal Movement)	Anilazene Chloroneb Chlorothalonil Etridiazole Mancozeb Quintozene Thiram
Localized Penetrants	
(Little Significant Movement)	Iprodione (limited) Propamocarb (limited) Vinclozolin (limited)
Systemic Penetrants	
(Mostly Upward Movement)	Cyproconazole Flutolanil Fosetyl-al (up/downward) Metalaxyl Propiconazole Thiophanate Methyl Triadimefon

The way in which systemic penetrant fungicides move inside the plant influences the manner in which they should be applied in order to maximize their effectiveness. These properties should be taken into consideration in developing any sound disease control strategy that includes systemic penetrant fungicides. In general, foliar disease control with systemic penetrant fungicides is more prolonged when the fungicides are drenched into the root zone. For example, foliar applications of systemic penetrant fungicides provide excellent short-term control of foliar diseases whereas drenching the fungicide into the root zone provides a much longer period of protection as well as control against root and crown diseases. On the other hand, root disease control with systemic penetrant fungicides is only possible if they are drenched into the root zone.

Penetrant fungicides have the advantage over contact fungicides in that they generally have a longer residual action. For example, only 3-10 days of control can generally be expected from a contact fungicide, which means that it takes only 3-10 days for the disease to reappear following the fungicide application. On the other hand, penetrant fungicides may provide at least 21-28 days of control. In addition to protecting newly-formed plant tissues, penetrant fungicides have the added advantage of being able to suppress pathogens that have already infected plant tissues.

Penetrant fungicides currently on the market prevent turfgrass pathogens from growing. This is usually accomplished through a very specific mode of action (see below), which must be understood to properly manage fungicide resistance. This will also be discussed later.

Decades ago many of the older materials such as mercury- and cadmium-based fungicides had little or no selectivity and were considered to be general biocides, killing most everything living in soil. Other currently-used contact fungicides such as anilazine, mancozeb, and thiram also have little selectivity, but are generally more environmentally compatible than the cadmium and mercury fungicides. A number of the newer penetrant fungicides are either so selective that only certain taxonomic groups of turfgrass pathogens are affected (e.g., metalaxyl, fosetyl-al, and propamocarb), or they are quite broad spectrum.

Often it is difficult to know how these fungicides will behave in turfgrass soils and how plants will respond without knowing more about the properties of the fungicides, the behavior of turfgrass plants, the physical and chemical properties of the soil, and the level of microbial activity in thatch and soil.

5.2.5 How Fungicides Work

Fungicides are designed to disable fungi by inhibiting a number of metabolic processes in fungal cells. The cellular location and the biochemical pathway or enzyme inhibited by the toxic action of the fungicide imparts some selectivity upon the fungicide being used. The specific modes of action of a number of currently available turfgrass fungicides are listed in Table 5.2.3.

Turfgrass fungicides can all be grouped according to their general chemical class. Currently there are ten different classes for turfgrass fungicides. The different fungicides found within each class all possess similar mechanisms of action whereas fungicides in different classes have different modes of action. The only exceptions to this rule are the fungicides found in the aromatic hydrocarbon and dicarboximide groups. Fungicides in each of these groups have very similar modes of action.

Table 5.2.3 Specific modes of action and risk of resistance of commonly used turfgrass fungicides

Fungicide Class	Fungicide(s)	Function Affected	FRAC Codes*	Risk of Resistance
Aromatic Hydrocarbons	Quintozene	Membrane function	14	Low to Not Significant
	Chloroneb		14	
	Etridiazole		14	
Benzimidazoles	Thiophanate Methyl	Nuclear function	1	High
Carbamates	Mancozeb	Membrane biosynthesis	28	Moderate
	Propamocarb		28	
	Thiram		28	
Carboximides	Flutolanil	Respiration	7	Moderate
	Boscalid	Respiration	7	
Cyanoimidazole	Cyazofamid	Mitochondrial inhibition	21	Unknown
Dicarboximides	Iprodione	Membrane function	2	Moderate
	Vinclozolin		2	
Diverse	Mineral Oils	Diverse	NC	Not Known
Nitriles	Chlorothalonil	Respiration	M5	Not Significant
Phenylamides	Metalaxyl	Nucleic acid synthesis	4	High
	Mefenoxam		4	
Phosphonates	Fosetyl-al	Amino acid metabolism (Fungi)	33	Low
	Phosphites	Improved host defenses (Plants)	33	
Sterol Biosynthesis	Cyproconazole	Membrane function	3	Moderate
Demthylation Inhibitors	Propiconazole	Membrane function	3	Moderate
	Triadimefon		3	
	Fenarimol		3	
	Myclobutanil		3	
Phenylpyrrole	Fludioxinil	Signal Transduction	11	Low-Medium
Strobilurins	Azoxystrobin	ATP inhibition	11	High
	Pyraclostrobin		11	
	Trifloxystrobin			
Antibiotic	Polyoxin D	Chitin (cell wall) production	19	Moderate

Source: Köller, W., Ed. 1992. Target Sites of Fungicide Action, CRC Press, Boca Raton, 328 pp.

Burpee, L. 2006. Guide to Turfgrass Fungicides, University of Georgia Cooperative Extension

*FRAC codes indicate the biochemical target site of action, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk of resistance.

Fungicides suppress the activity of fungal pathogens either by killing fungal cells (fungicidal) or by simply suppressing growth and reproduction (fungistatic). Those fungicides that affect cell properties and processes common to a wide variety of organisms, such as nuclear function or membrane biosynthesis, generally have a wider spectrum of activity than do those affecting more specific functions such as specific respiratory enzymes, etc. These broad spectrum contact fungicides would include chlorothalonil, mancozeb, and thiram as well as the broad-spectrum systemic penetrant fungicides such as the benzimidazoles (thiophanates) and sterol inhibitors (triadimefon, propiconazole, etc.).

5.3 Achieving Maximum Levels of Disease Control from Fungicide Applications

The goal of any fungicide disease control program should be to deliver the appropriate dosage of the most effective fungicide to the target at the proper time. In order to maximize the efficacy of the fungicide, we need to consider a number of soil, plant environmental, equipment, and fungicide factors.

5.3.1 Behavior of Fungicides in Soil

The efficacy of fungicides in turfgrass soils can be related to their behavior in soil. An understanding of the factors that affect fungicide behavior can ultimately lead to more effective fungicide applications. This type of information is among the most important in choosing and predicting the outcome of fungicide applications.

5.3.2 Fungicide Efficacy Affected by Soil Properties

Since turfgrass pathogens are generally soil-inhabiting fungi, turfgrass fungicides nearly always must find their way to the soil or thatch for effective disease control. The soil-thatch interface under a turfgrass canopy is without a doubt, one of the most difficult environments in which to apply fungicides successfully. There are many factors that reduce the activity of soil-applied fungicides in this zone. Most commonly they can be immobilized, degraded, dissipated, and inactivated quite rapidly. This is related to a number of factors, including the degree of sorption of fungicides to organic matter and soil particles, the amount of microbial and chemical degradation, photodecomposition, root absorption, and movement out of the soil profile through volatilization and leaching.

5.3.3 Sorption of Fungicides to Thatch and Soil

Most turfgrass fungicides readily bind to and are immobilized in thatch and soil organic matter. While this is desirable from the point of view of minimizing the movement and leaching of fungicides, it can be detrimental in that it prevents fungicides from achieving their maximum levels of control. In particular, it prevents fungicides applied for the control of root and crown pathogens from reaching their target. Furthermore, adsorbed fungicides are generally more persistent, providing greater opportunities for undesirable side-effects.

Table 5.3.1. Water solubility and thatch adsorption potential of turfgrass fungicides

Fungicide	Water Solubility (ppm)[a]	Potential for Thatch Adsorption[b]
Quintozene	0.1	High
Chlorothalonil	0.9	High
Thiophanate methyl	3	Low
Vinclozolin	3.4	High
Mancozeb	6	High
Anilazene	8	High
Chloroneb	8	High
Flutolanil	9.6	Unknown
Iprodione	13	Moderate
Fenarimol	13.7	Moderate
Thiram	18	Moderate
Triadimefon	64	Low
Etridiazole	117	Moderate
Propiconazole	100	Moderate
Cyproconazole	140	Moderate
Metalaxyl	8400	Low
Fosetyl-al	120,000	Low
Propamocarb	1,005,000	High

[a]Solubility over 30 ppm is considered high.
[b] Low adsorption = K_{oc} values ≤300;
Moderate adsorption = K_{oc} values between 300 and 1000;
High adsorption: = K_{oc} values >1000.

Fungicides vary in the degree to which they are adsorbed to soil particles and organic matter. This is mainly a function of the physical and chemical properties of the soil, the chemical properties of the fungicide, and the environmental conditions. The organic matter content is by far the most important determinant of fungicide adsorption. Since mature stands of turf may have a considerable thatch layer, this can present real problems in maintaining effective fungicide treatments.

All things being equal, as the thatch layer or soil organic matter content increases, the greater will be the degree of fungicide adsorption. Those fungicides most likely to be immobilized in thatch include contact fungicides such as anilazene, chlorothalonil, mancozeb, chloroneb, quintozene, and etridiazole, and the penetrant fungicides propamocarb and vinclozolin (Table 5.3.1).

5.3.4 Soil Properties Important in Fungicide Adsorption

Soil type can also affect the immobilization of turfgrass fungicides. As the clay content and the cation exchange capacity (CEC) increase, so too does the degree of fungicide adsorption. Typically, on golf course turf, however, high sand content growing mixes and highly-modified soils limit the clay content in the root zone. However, organic amendments as well as some types of inorganic amendments that increase CEC (e.g., zeolites) may have significant effects on fungicide efficacy.

Soil temperature may also affect fungicide adsorption. In general, as soil temperatures increase, adsorption decreases. For those fungicides that have a greater potential for thatch adsorption, the effects of soil temperatures on adsorption are much more pronounced.

Particularly for fungicides that are more soluble in water, wide changes in soil pH will drastically alter the degree of fungicide adsorption. For example, considerably more adsorption would be expected in alkaline (pH ≥ 7.0) soils than in acidic (pH ≤ 5.5) soils. This is not particularly important if soil pH from site to site is relatively uniform. Soil water content may also affect fungicide adsorption insomuch as adsorption increases dramatically in very dry soils.

5.3.5 Fungicide Properties Affect Adsorption

The chemical properties of the fungicides being applied are important predictors of soil or thatch adsorption. Polar or permanently charged fungicide molecules are more likely to be adsorbed than neutral or non-polar molecules. In general, polar fungicides remain more polar in alkaline than in acidic environments. Most of the turfgrass fungicides used today, however, are quite non-polar with the exception of fosetyl-al which is the most polar of all the turfgrass fungicides.

Of equal importance is the water solubility of the fungicide (Table 5.3.1). As the water solubility increases, the amount of adsorption generally decreases. For the most part, many of the contact fungicides are not readily soluble in water and may be tightly adsorbed to thatch. Those fungicides that are least likely to adsorb because of their higher water solubility are fosetyl-al, metalaxyl, and triadimefon. Propamocarb is an unusual fungicide, in that it is extremely water soluble, but is also highly adsorbed to organic matter whereas thiophanate methyl has a low solubility but a low potential for thatch adsorption because of other fungicide properties.

5.3.6 Microbial Degradation of Fungicides

All turfgrass fungicides are subject to varying degrees of microbial, plant, and chemical degradation in soil. It is the only process whereby the fungicide can actually disappear from the environment. Since many soil microbes get their energy from the breakdown of carbon-containing compounds, all turfgrass fungicides have the potential to serve as a food source for microorganisms in turfgrass soils. Even if the fungicide does not serve directly as a food source, decomposition may still occur as soil microbes break down other forms of organic material. Frequently the active ingredient molecule is broken down into yet another molecule with no fungicidal or detrimental side effects. However, in some cases (e.g., triadimefon), the fungicide active ingredient is broken down into yet other fungicidal compounds that have their own behavior and efficacy in turfgrass soils.

Generally, the greater the soil microbial populations and the greater the microbial activity, the more likely a fungicide will degrade. However, studies have shown that microbial degradation of pesticides does not occur immediately after the application of the material. Rather, there is a lag period during which microbial populations shift, favoring those microbes possessing the appropriate enzyme systems to degrade the introduced pesticide. After these microbial populations acclimate to the introduced fungicide, degradation can proceed at a higher rate. This is why, over time, the continued application of the same fungicide to the same site can result in reduced fungicide efficacy, if not from enhanced microbial degradation, then from the development of fungicide resistance (see below).

5.3.7 Soil Properties Affect Microbial Degradation

The rate at which turfgrass fungicides are degraded by soil microbes depends, to a large extent, on fungicide chemical properties and fungicide concentration, but also on a number of soil factors including moisture, pH, oxygen content, nutrient status, clay content, organic matter content, and, perhaps most importantly, the type of soil microbial community. The variety of soil microorganisms that degrade turfgrass fungicides have very specific metabolic capabilities. The level of fungicide degradation is directly proportional to the population levels of these specific microbes. As these microbes degrade the active fungicide molecules, the degradation products further stimulate other microorganisms capable of degrading the fungicide metabolites.

Those fungicides more resistant to microbial degradation are those that are less available in the soil solution. For example, those fungicides that more readily bind to thatch, are not very water soluble, and are known to persist in soil for appreciable periods of time, will be less likely to be subject to microbial degradation. This persistence in soil is usually expressed as the half-life of the fungicide, which means the time it takes for half of the original applied fungicide to disappear (Table 5.3.2).

Table 5.3.2. Half-life and persistence of turfgrass fungicides in soil

Fungicide[a]	Half-Life in Soil	Persistence Classification
Fosetyl-al	20 Min.-1.5 Hr	Very short
Anilazene	0.5-1 Days	Very short
Thiram	0.5-15 Days	Short
Vinclozolin	1-31 Days	Moderately short
Chlorothalonil	5-90 Days	Moderately short
Mancozeb	6-139 Days	Moderately persistent
Triadimefon	6-28 Days	Short
Iprodione	7-160 Days	Moderately short
Propamocarb	10-27 Days	Short
Chloroneb	10-180 Days	Moderately Short
Thiophanate methyl	10-28 Days	Short
Etridiazole	20 Days	Short
Fenarimol	20-365 Days	Highly persistent
Quintozene	21-434 Days	Highly persistent
Flutolanil	40-60 Days	Moderately short
Propiconazole	40-123 Days	Highly persistent
Metalaxyl	70-160 Days	Moderately short
Cyproconazole	80-100 Days	Moderately persistent

[a] Fungicides ranked from the shortest half-life to the longest

5.3.8 Volatilization of Fungicides

Volatilization refers to the evaporation of fungicides from the spray, the turfgrass foliage, and the soil surface into the atmosphere. Volatile losses of fungicides are significant from two different perspectives. First, volatile losses remove the fungicide from the target site thus reducing the effectiveness of the fungicide. Second, volatile losses increase the inhalation hazard to applicators and others coming in contact with treated turf. Therefore, efforts should always be made to minimize these losses where possible.

The degree of volatilization of a given turfgrass fungicide is related not only to the inherent vapor pressure of the fungicide at a given temperature (Table 5.3.3), but also on environmental factors and chemical processes at the soil-air-water interface. For example, volatilization may be affected by the soil water content and bulk density. Generally, as soil water content increases, volatilization decreases. However, in very dry soil, volatilization is also reduced as increased adsorptive processes limit the amount of fungicide free in the soil solution. Increases in bulk density tend to reduce the diffusion of the fungicide to the soil surface and further increase fungicide adsorption.

Table 5.3.3. Vapor pressures of turfgrass fungicides and their potential for volatilization

Fungicide	Vapor Pressure[a] (mPa)	Potential for Volatile Losses
Chloroneb	400.0	High
Etridiazole	19.0	High
Quintozene	12.7	High
Thiram	2.3	Moderately High
Flutolanil	1.77	Moderately High
Propamocarb	0.800	Moderate
Metalaxyl	0.75	Moderate
Chlorothalonil	0.076	Low
Fenarimol	0.065	Low
Triadimefon	0.06	Low
Vinclozolin	0.016	Low
Fosetyl-al	0.013	Low
Thiophanate methyl	0.0095	Very Low
Propiconazole	0.0056	Very Low
Cyproconazole	0.00346	Very Low
Anilazene	0.0000008	Very Low
Iprodione	0.0000005	Very Low
Mancozeb	negligible@20ºC	Very Low

[a] Fungicides ranked from most volatile to least volatile based on volatility at 20-25ºC.

Precipitation and irrigation will also reduce the amount of volatilization by transporting fungicides away from the turfgrass foliage and soil surface where the greatest amount of volatilization occurs. It also increases the soil water content, thereby reducing volatilization. The frequency of rainfall or irrigation can also affect volatilization indirectly by affecting the degree of water evaporation. Water evaporation will transport most fungicides to the soil surface where volatilization can occur. The greater the frequency of irrigation or rainfall, the lower the potential for volatilization losses.

Wind speed may indirectly increase volatile losses of fungicides by increasing water evaporation rates. Generally, wind serves to mix the stagnant layer of air adjacent to the turfgrass foliage thereby increasing the overall evaporation rates and increasing the volatilization potential of turfgrass fungicides. Those fungicides that adsorb more tightly to thatch and soil will be unaffected by evaporative processes, but those that are normally free in the soil solution may have considerable increases in volatilization losses.

It is important to note that the greatest volatilization losses occur during application and within a few hours after application. Furthermore, volatilization losses are greater at warmer temperatures, particularly during the middle to latter part of the day. Therefore, if the fungicide being applied is particularly prone to volatilization losses, precautions should be taken to adjust application schedules. Second, the concentration of the applied fungicide affects the degree of volatilization; the greater the fungicide concentration, the greater its vapor concentration. Therefore, reducing application rates will help to minimize volatile losses of fungicides.

Additionally, it is important to recognize that the formulation of the fungicide will also affect its degree of volatilization. Wettable powder and granular formulations generally have a greater volatilization potential because a thin film remains on the turfgrass foliage or the granular particles remain on the soil surface following application. Some studies have linked volatile losses with the degree of dislodged fungicide residues. Therefore, the greater the degree of soil incorporation of the fungicide, the lower will be the volatilization of the fungicide.

5.3.9 Fungicide Leaching

Fungicide leaching can occur when the applied fungicide moves past the turfgrass root zone. This is the result of it not being taken up by the plant, degraded by soil microbes, broken down by chemical reactions in soil, decomposed by light, adsorbed to thatch and clay particles, or volatilized. In general, turfgrass fungicides as a group are not particularly susceptible to significant amounts of leaching when applied to mature stands of turf grown on soils with some level of organic matter or clay. However, greater application care must be taken when applied to thin, immature turf on high sand content soils followed by considerable amounts of rainfall or irrigation.

Of all the turfgrass fungicides, fenarimol, metalaxyl, propiconazole, and triadimefon have the highest potential for leaching. However, these fungicides pose little or no hazard under normal climatic conditions and operating procedures.

5.3.10 Management Recommendations

It is important to understand the behavior of fungicides in soil. Soil properties should be used as a guide in making decisions about the application of specific fungicides to specific sites for specific disease problems.

Much of the behavior of the fungicide being applied can be predicted from some knowledge of the soil properties and the environmental conditions at the site. For example, if faced with the decision of what fungicide to apply to a golf green with brown patch symptoms, you could choose from a vast number of products and formulations all labeled for brown patch control. If the green to which you were applying the fungicide was a native soil green with a high clay and organic matter content, you may want to choose a fungicide such as cyproconazole or propiconazole. Both have higher water solubility and lower potential for adsorption to clay and organic matter than do many other brown patch fungicides. On the other hand, if the green was a high sand content green in an exposed sunny area, you may want to choose a fungicide such as iprodione that has a relatively short half-life in soil and is relatively non-persistent. This would avoid any potential leaching losses. Furthermore, on this type of a green, soil temperatures and evaporation rates would be expected to reach relatively high levels, increasing the chances of volatilization losses. Since iprodione has a very low volatilization potential, a short persistence, and a relatively low potential for adsorption, this would be an ideal choice for that site.

Aside from choosing the fungicide based on its inherent properties and the soil conditions, making small adjustments in application rates, timing, formulation, and post irrigation will help to maintain the maximum amount of fungicidal activity. Furthermore, thatch management is critical to maintaining minimal immobilization and maximum efficacy.

5.4 Plant and Pathogen Factors Affecting Fungicide Efficacy

5.4.1 Turfgrass Growth and Vigor Affect Fungicide Absorption and Translocation

An important consideration when estimating the overall efficacy of fungicide applications is the growth of the turfgrass plants. Vigorously growing plants not only have a greater natural defense mechanism to pathogen attack, but they also take up penetrant fungicides more readily. Both situations improve the effectiveness of disease control programs.

Vigorously growing turfgrass plants are not to be confused with excessive turfgrass growth. Vigorously growing plants are those in a balanced state of growth where top growth is such that the root system can supply adequate levels of water and nutrients, maintaining the plant in a metabolic balance. Excessively-growing plants are those that are producing more top growth than the root system can adequately handle, creating a metabolic imbalance wherein the turfgrass foliage remains more succulent and more susceptible to foliar diseases such as leaf spots and leaf blights. This is particularly the case if the turfgrass foliage remains wet for prolonged periods of time. So, although vigorous growth is desirable, excessive growth should be avoided.

In healthy turfgrass plants, water and minerals move from the soil into the roots where they are translocated to the turfgrass foliage. On the other hand, the carbon-containing products of photosynthesis are either used for foliar growth and development or transported to the root system to support root growth and development. These processes of translocation require a properly functioning vascular system, made up of the xylem (upward translocating elements) and phloem (downward translocating elements).

The uptake and translocation of fungicides within turfgrass plants is equally dependent on a properly functioning vascular system. Most systemic penetrant fungicides move through the plant by way of the xylem and are thus translocated upward in the plant. One fungicide, fosetyl-al, may actually move in both the xylem and the phloem. The movement of fungicides in plants is further facilitated by transpiration, or the evaporative loss of water through the leaf stomata. This usually increases the upward movement of fungicides in the xylem.

Generally, the more vigorous the growth of the turfgrass plant, the more movement of water and photosynthate through the vascular systems and the higher the rates of transpiration. Likewise, in a vigorously growing plant, the greater the uptake and translocation of penetrant fungicides. For this reason, systemic penetrant fungicides should never be applied to dormant turf.

It is not advised to apply systemic penetrant fungicides to severely diseased turf, particularly if affected by root pathogens. Many root- and crown-infecting fungi may cause extensive damage to root systems long before symptoms appear on the above ground parts of the plant. This dysfunctional root system is unable to properly absorb and translocate penetrant fungicides. Therefore, in cases of severe disease development, contact fungicides would be preferred over systemic penetrant fungicides.

5.4.2 Turfgrass Stresses Important to Fungicide Performance

Stresses on turfgrass plants are particularly important considerations in fungicide efficacy. The more compromised the plant, whether due to heat stress, drought stress, traffic stress, soil compaction, fertility stresses, etc., the plants are weakened and become predisposed to infection by pathogens that would otherwise not typically be a problem. Similarly, plant infection and disease development may be enhanced in stressed turf allowing pathogens to develop much faster and symptoms to progress much more quickly than would otherwise be the case.

5.4.3 Pathogen Factors Affecting Fungicide Efficacy

Aside from the consideration of the overall health and vigor of the turfgrass plant, there are a number of pathogen attributes, including the life stage, inoculum properties, plant tissues affected, and inherent fungicide sensitivities, that can influence the performance of fungicides.

5.4.3.1 Life Stage

Of particular importance to the performance of fungicide applications is the life stage of the pathogen. Turfgrass pathogens follow a cyclic chain of events during the development of turfgrass diseases. These events include the developmental stages of the pathogen as well as a progression of plant responses. All infectious turfgrass disease causing agents go through such a disease cycle.

If we use fungal pathogens as an example, the overseasoning stage of most fungal turfgrass pathogens occurs in the winter months where the pathogen persists either in soil, thatch, or in root and crown tissues as a quiescent spore or other form of inoculum. Snow mold pathogens are the exception to this rule. They overseason during the summer months. When temperature and moisture conditions again become favorable, inoculum can be transported to adjacent healthy turfgrass plants either by wind, rain, moving water, equipment, etc.

Once at the surface of the healthy plant, the spore can then germinate and penetrate the plant tissues. In penetrating tissues, a nutritional relationship is eventually established between the pathogen and the plant. It is at this stage that the plant is considered to be infected. As the pathogen continues to grow between and within cells of the host plant, it can rapidly invade adjacent tissues and organs. It is during this invasive stage that plant symptoms become apparent. Eventually a new batch of spores is produced on and within infected plant tissues. These spores can be again transported to adjacent healthy plants where it initiates secondary disease cycles, or they can overseason in a quiescent state once again.

The dormant overseasoning period of turfgrass pathogens is a particularly important aspect of pathogen biology and important to the efficacy of fungicide applications. Typically, this dormant phase allows the fungus to survive adverse environmental conditions, usually during the winter months. However, for some pathogens (e.g. *Typhula* spp.), the dormant stage occurs during the summer months. Many pathogens may have dormant periods throughout the growing season in response to drastic changes in soil environmental changes and in response to certain pesticide applications. During this dormant stage, the pathogen is generally resistant to most fungicides, particularly those with only fungistatic activity (i.e., many of the penetrant fungicides). Only a few contact fungicides will actually destroy dormant pathogen propagules.

The importance of understanding this cyclic nature of diseases to fungicide applications becomes apparent when one considers that each stage in the disease cycle is required for the next stage. Most fungicide applications are aimed at preventing spore germination, penetration, and invasion of the fungal pathogen on and in turfgrass plants. For the most part, fungal pathogens prefer continuously moist conditions where temperatures are ideal for spore germination, growth, and plant infection (Table 5.4.1). Therefore, it can be assumed that, with the exception of those pathogens that prefer exceptionally warm (some *Pythium* and *Rhizoctonia* species) or exceptionally cool (*Typhula* and *Microdochium* species as well as some *Pythium* species) conditions, fungicide applications will have the highest level of efficacy when applied during relatively cool to moderately warm conditions since the majority of pathogens could be in an active state of growth and most sensitive to the applied fungicide.

5.4.3.2 Inoculum Properties

The germination of spores is a particularly sensitive stage in the life cycle of fungal turfgrass pathogens. Nearly all of the fungicides used in turfgrass management are capable of inhibiting spore germination as well as spore production and other active stages of the life cycle. However, some fungicides are more limited in action and only inhibit spore germination but not spore production (e.g. iprodione) and may not be as effective against some pathogens under certain environmental conditions as other fungicides.

The density of inoculum (i.e. the population level of the pathogen) and the nutrition of the pathogen will greatly affect the efficacy of fungicide applications. The higher the pathogen population, the higher the rates of fungicides needed to achieve effective control and possibly the more frequently applications need to be made.

Additionally, the greater the nutrition and vigor of the pathogen, the less sensitive the fungus will be to fungicide applications. During active disease development, usually both the nutrition and the population level of the pathogen are elevated, making disease control more problematic. This is the reason that most turfgrass fungicide labels contain both low and high label rates. If applied before the disease has a chance to develop to any significant degree, the lower rates are generally suitable for effective disease control.

5.4.3.3 Plant Tissues Affected

The plant tissues most commonly infected by the target pathogen will influence not only the choice of fungicide but also the effectiveness of a given fungicide. Whereas fungicide applications for the control of foliar diseases are relatively straightforward; the control of root diseases is often difficult. The control of perennial infections in root tissues presents special logistic problems that generally require the use of penetrant fungicides. Once pathogens

Table 5.4.1. Temperature and moisture conditions favoring the activity of turfgrass pathogens

Pathogen	Disease	Optimum Temperature	Required Moisture Period for Spore Germination
Colletotrichum graminicola	anthracnose	22-28° C (71-82° F)	4-6 hr
Rhizoctonia solani	brown patch	23-32° C (73-90° F)	5-7 hr
Rhizoctonia zeae	brown patch	33° C (91° F)	4-8 hr
Sclerotinia homoeocarpa	dollar spot	16-27° C (61-81° F)	8-24 hr
Magnaporthe grisea	gray leaf spot	24-28° C (75-82° F)	16-24 hr
Dreschlera spp.	leaf spot	12-16° C (54-61° F)	12-24 hr
Bipolaris spp.	leaf spot	25-35° C (77-95° F)	8-48 hr
Leptosphaeria korrae	necrotic ringspot	20-25° C (68-77° F)	48-72 hr
Microdochium nivale	pink snow mold	7-19° C (45-66° F)	48-72 hr
Pythium aphanidermatum	Pythium blight	30° C (86° F)	14 hr
Pythium spp.	Pythium root rot	13-18° C (55-64° F)	48-72 hr
Laetisaria fuciformis	red thread	16-21° C (61-70° F)	4-24 hr
Puccinia, Uromyces	rusts	18-22° C (64-71° F)	3 hr
Entyloma, Urocystis, Ustilago	smuts	10-18° C (50-64° F)	24 hr
Magneporthe poae	summer patch	25-30° C (77-86° F)	48-72 hr
Gaeumannomyces graminis var. Avenae	take-all patch	20-25° C (68-77° F)	48-72 hr
Typhula spp.	Typhula blight	5-10° C (41-50° F)	Days to weeks

Compiled from: Couch, H. B. 1995, Smiley, R. W., P. H. Dernoeden, and B. B. Clarke 1992, and Smith, J. D., N. Jackson, and A. R. Woolhouse 1989.

infect root tissues, they are inaccessible to contact fungicides. Furthermore, unless penetrant fungicides are absorbed by roots or translocated to root tissues, diseases from root-infecting pathogens will not be effectively controlled. In most instances proper fungicide selection can overcome some of the difficulties with root diseases.

5.4.4 Pathogen Sensitivities to Fungicides Vary

It is also important to note that fungal pathogens vary widely in their inherent sensitivity to fungicides. It is clear that pathogens causing different diseases vary in their sensitivity to specific fungicides. But different strains of a single pathogen may also vary in their sensitivity to the same fungicide. This raises some important considerations when interpreting University fungicide trials. Those fungicides that are most efficacious in a fungicide trial may not necessarily be the most effective on your particular site. Whereas results of research trials with various fungicides may reveal some general trends in fungicide efficacy and in the variability in pathogen sensitivities.

5.4.5 Fungicide Resistance

One of the more important and emerging issues with the use of fungicides having a narrower mode of action is fungicide resistance. Fungicide resistance becomes particularly serious when prolonged and continued applications of fungicides with the same mode of action are made to the same turfgrass site. The reasons for the development of such resistance are related largely to the fungicides mode of action and to the biology of turfgrass pathogens.

For the most part, many of the fungicides used for turfgrass disease control, especially the penetrant fungicides, do not actually kill pathogen populations. Rather, they stop the mycelial growth and spore germination of the fungus, often forcing the fungus into a dormant state. As mentioned previously, in this dormant state, the fungus can remain alive, but is no longer sensitive to the applied fungicide. In this particular situation, disease resulting from the germination of previously-dormant spores following the fungicide application may appear as if the pathogen was resistant to the fungicide when, in fact, it was not sensitive only because of its dormancy.

Even though fungicide applications may be effective in stopping the immediate development of the disease, they tend to maintain soil populations of turfgrass pathogens, insuring that the same disease will appear time after time if the environmental conditions are appropriate. Because of the genetic diversity within most fungal pathogen populations, a small proportion of the population of any turfgrass pathogen will be insensitive to a given fungicide. If the fungicide to which that small proportion is resistant is applied continually to the same site or applied at less than optimum rates, this provides a means of selection for that resistant portion of the pathogen population. Therefore, as the fungicide continues to eliminate the sensitive population, the resistant population slowly dominates, becoming even more resistant and eventually making the fungicide totally ineffective for that disease on that particular site.

5.4.6 Minimizing Fungicide Resistance

Whenever possible, the frequent and continued use of the same fungicide or combinations of fungicides with the same modes of action should be avoided. For the specific modes of action and risk of resistance of all commonly used turfgrass fungicides, refer to Table 5.2.3.

In an effort to assist turfgrass managers with resistance management, FRAC Codes are provided. FRAC (Fungicide Resistance Action Committee) is a group of scientists representing chemical manufacturers: codes are available at www.frac.info. These codes are not required but EPA has made their inclusion on the label voluntary. This will allow turfgrass managers to more effectively rotate (or tank mix) among fungicides with different sites of action.

The following steps should be considered in any attempt to reduce the risk of fungicide resistance problems:

1. As the first line of defense against any disease problem, incorporate disease-resistant or disease-tolerant turfgrass cultivars or varietal mixtures into the turfgrass site whenever practical.
2. Attempt to minimize the problem by employing cultural or biological methods of disease control. No known resistance has occurred in response to a cultural or biological disease control strategy.
3. If you must use fungicides, make sure that the same fungicide is used for no more than two successive applications before rotating to a different fungicide with a different mode of action.
4. Avoid applications at less-than-label rates. Also to assist in this, make sure that the proper amounts of fungicide are placed in the spray tank and mixed with the appropriate amounts of water. Care should also be taken to assure that your equipment is properly calibrated and delivering the correct levels of fungicide to the turf. Consult *Diseases of Turfgrasses*, Third Edition by Houston Couch for more information.
5. Make sure that you are getting complete spray coverage, avoiding skips and overlaps.
6. Finally, avoid preventive applications whenever possible.

5.4.7 Management Recommendations

The best advice here is to constantly monitor your sensitive turfgrass sites, and get early diagnoses on potential disease problems. Early detection and diagnosis will allow you to apply the proper fungicide at the earliest stages of disease development when plants are still functioning relatively well and the pathogens are clearly active yet only beginning to build up populations. Following these principles will increase the likelihood of getting adequate fungicide uptake and distribution inside the plant, and of catching the pathogen at its most sensitive stage. This should also reduce the amount and frequency of the fungicide applied, making for more economical applications and more effective disease control. Finally, always be aware of the potential of fungicide resistance and take the proper precautions to avoid it.

5.5 Handling and Applying Fungicides

Acquiring knowledge of fungicide properties and their behavior in soils and plants is only half the job of implementing an effective and environmentally responsible fungicide program. Undoubtedly the most important part of this process is making sure that you are delivering the proper amounts of the correct fungicide to the appropriate place at the right time. To assure this, routine monitoring of your application procedures and equipment is necessary.

It is important, therefore, that care be taken in measuring, mixing, and loading fungicides and in routinely calibrating and maintaining equipment. Further precautions should be taken to assure proper timing and placement of fungicide applications.

5.5.1 Measuring, Weighing, and Mixing Fungicides

It is important that the proper protective clothing, including chemical-resistant gloves, goggles, and a respirator be worn when handling any fungicide since the concentrated forms of the fungicides can be particularly dangerous if splashed onto your skin or in your eyes. At a minimum, you'll need to use the protective equipment listed on the pesticide label. Also, some fungicide formulations such as wettable powders may be quite dusty during handling and may easily be inhaled. It is important to avoid smoking, eating, or drinking during fungicide handling operations since you could easily carry the fungicide to your mouth with contaminated hands or food. In general, utmost cleanliness and hygiene should be practiced during any and all fungicide handling operations.

Nearly all fungicides commonly used for turfgrass disease control are purchased as concentrated formulations and require some sort of measuring and mixing to dilute the fungicide prior to application. The amount of mixing and handling depends to a large extent on the type of formulation. Many granular formulations come packaged in bags in sufficient quantity to cover a designated area. Similarly, water soluble packets contain prepackaged fungicide formulations that are mixed with water and used to treat a designated area. In both of these cases, minimal measuring and weighing are required. However, for formulations such as wettable powders (WP), water dispersible granules (WDG), emulsifiable concentrates (EC), and flowables (F or FLO), a certain degree of measuring, weighing, and mixing are necessary for proper application.

5.5.2 Fungicide Compatibilities

When mixing fungicides together with other pesticides, growth regulators, or fertilizers, the compatibility of the mixture can be a serious consideration in determining fungicide efficacy. In some cases, combinations resulting in enhanced levels of fungicidal activity have been identified. These include combinations of sterol inhibiting systemic fungicides and chlorothalonil for the control of a number of turfgrass pathogens, combinations of metalaxyl/mancozeb, fosetyl-al/mancozeb, chloroneb/thiram, and etridiazole/PCNB for the control of *Pythium* diseases, and anilazine/Zn (or Cu) for the control of anthracnose. However, in many cases, combinations of other chemicals with fungicides can reduce the efficacy of the fungicide. The physical and chemical compatibilities of the spray partners are of the most concern.

The physical compatibility of the materials should first be tested to be sure that no unwanted oily films and layers, foams, flakes, gels, or precipitates are formed. Additionally, wettable powders should be checked for lumps when mixed with some materials whereas some liquid formulations may settle into layers when mixed with other chemicals. Physical compatibilities can be tested easily by preparing the appropriate concentrations of tank-mixed components each in a small container. Add each component one by one to the fungicide suspension, shaking between each addition. When all of the components have been mixed together, gently shake the container and examine the contents immediately after shaking to see if there is any excessive foaming, and after 30 min to 1 hr to check for any precipitates. If the mixture does not look uniform, it should not be used as a tank mix.

The chemical compatibility of the tank mix partners should also be considered. Don't mix anything that will lead to a highly alkaline or highly acid condition, since this will lead to the degradation of some fungicides. Don't use adjuvants unless you know they are safe. If you are unsure of the phytotoxicity of a mixture, perform a test on a small area of turf before mixing on a large scale. Phytotoxicity can be affected by the air temperature, plant stress, plant genotype, etc. Finally, do not mix materials targeted for both foliar and root problems unless each material in the mixture behave similarly in the plant (e.g., they are each contact materials, each localized penetrants or each upwardly-moving systemic fungicides). Otherwise, less than optimal control will result for one of the diseases in the complex. Similarly, do not mix fungicides with essentially the same mode of action. This can lead to phytotoxicity.

Fungicide formulations are more effectively mixed with other chemicals of similar formulation. For example, liquids can be mixed more effectively with other liquids and wettable powders or water dispersible granules can be mixed with other wettable powders or water dispersible granules. However, it is also common to mix fungicides with other materials having different formulations.

When mixing liquids and solids in the same spray tank, it is important that they be added in the correct order to insure proper dispersion and uniformity. A convenient way to remember the proper order is to use the sequence W-A-L-E where W stands for wettable powders and water-dispersible granules, A stands for agitation, L stands for liquids, and E stands for emulsifiable concentrates.

The proper procedure is as follows:

- Add wettable powders and water dispersible granules first to a tank half full of water.
- Agitate until these formulations are uniformly dispersed while adding water until the tank is 90% full.
- Add all flowable liquids and other water soluble formulations.
- Finally, add emulsifiable concentrates.
- Top off the tank and continue agitation.
- The materials are now properly mixed.

As always, the tank contents should be properly and continuously agitated during spray operations since many formulations form suspensions and not true solutions. And finally, always consult the label for compatibility information. Most fungicide labels will list compatible or incompatible combinations when they are known and have been tested.

5.5.3 Tank Storage Time and pH Affect Fungicide Efficacy

Fungicides should, whenever possible, be mixed and sprayed as soon after mixing as possible. However, in cases where fungicide mixtures are placed in the spray tank in advance of the application, special precautions must be taken to avoid chemical decomposition of the fungicide as it sits in the tank. One of the primary factors contributing to the instability of a fungicide is the pH of the water.

Most of the water used to prepare fungicide sprays in the United States is quite alkaline (high pH). Studies have shown that under these alkaline conditions, a number of commonly used fungicides can break down and lose their effectiveness (Table 5.5.1).

For example, anilazene, chlorothalonil, thiophanates, and thiram are all hydrolyzed at pH values greater than 9.0. Some fungicides (such as fosetyl-al) are unstable at pH levels below 5.0. Fungicides such as iprodione, vinclozolin, propiconazole, and triadimefon are insensitive to pH and remain stable even after storage in the spray tank for 24 hr.

Even though many fungicides are relatively stable at extremes in pH, storage in the tank for prolonged periods of time will accelerate their decomposition and the loss of their effectiveness. For example, even though fenarimol is relatively stable when initially mixed, it is unstable at acid pH values when stored for 24 hours or more.

Because of the critical role of pH in fungicide efficacy, the water used for spray applications should be checked on a weekly basis and the pH adjusted if necessary. More importantly, the pH of the fungicide mixture should be determined and adjusted if necessary. A number of commercially available buffering agents are useful for such pH adjustments. A pH range of 5-6 is most desirable.

Table 5.5.1. pH stability and photostability of turfgrass fungicides

Fungicide	Comment
Chloroneb	Stable
Cyproconazole	Stable
Etridiazole	Stable
Flutolanil	Stable
Metalaxyl	Stable
Propamocarb	Stable
Propiconazole	Stable
Triadimefon	Stable
Fosetyl-al	Unstable in acidic (pH<2) and alkaline (pH>9) conditions
Anilazene	Unstable at pH>9
Chlorothalonil	Unstable at pH>9
Mancozeb	Unstable at pH>7
Quintozene	Unstable at pH>9
Thiophanate methyl	Unstable at pH>9
Thiram	Unstable at pH>9
Vinclozolin	Unstable at pH>9
Fenarimol	Photodecomposes rapidly
Iprodione	Unstable at pH>7, Photodecomposes in aqueous suspensions

Compiled from: Tomlin, C., 1994. The Pesticide Manual, 10th Edition, Crop Protection Publications, British Crop Protection Council, UK, 1341 pp.

5.5.4 Timing of Fungicide Applications

The timing of fungicide applications is another critical aspect of maximizing fungicide performance. Of obvious importance is the timing of an application relative to the active stages of the pathogen. However, other timing considerations include the time of day, temperature/ humidity relationships, wind patterns, and practical considerations of traffic.

For optimum disease control, fungicide applications must be timed to coincide with periods when the target pathogen is in an active growth stage. This is the stage most susceptible to fungicide treatment. Most often these periods of pathogen activity correspond with symptom development in the turfgrass plant. Therefore, most fungicide applications are best made as a curative application after a correct diagnosis has been made. However, with some diseases, the period of maximum pathogen activity precedes the development of symptoms, sometimes by several months. This is the main reason why fungicides used for summer patch control must be applied in the late spring even though summer patch symptoms typically appear in mid to late summer. Pathogens in a dormant stage are generally not susceptible to fungicides.
Another important timing consideration is the time of day, particularly as it relates to temperature and humidity relationships. Both temperature and humidity can affect fungicide drift. The higher the temperature and lower the relative humidity, the greater the opportunity for fungicide evaporation or volatilization. This can be avoided by applying early in the morning when temperatures are lower and relative humidities are higher than is normally the case during the middle parts of the day.

In addition to the reduced drift hazard from fungicide volatilization early in the morning, drift may also be minimized in the morning hours because of calmer winds and lower convective air turbulence. As the turf surface heats up and solar radiation becomes stronger during the day, a greater temperature differential occurs between the turfgrass surface and the air. This creates upward air currents that can carry spray droplets away from the target site.

5.5.5 Fungicide Placement

Fungicide placement is one of the more important factors affecting fungicide performance. Generally, if the fungicide does not come in contact with the pathogen, the disease will not be controlled. The nature of the disease to be controlled, the amount of thatch, and some of the inherent properties of the fungicide being used all determine where the fungicide should be placed. For example, if the disease to be controlled is caused by a pathogen that infects and survives in the foliage, placement of the fungicide is generally not a problem. The fungicide can simply be applied as a spray. However, if the disease to be controlled is caused by a root-infecting pathogen, placement of the fungicide becomes more problematic. The main difficulty in placing the fungicide in contact with root pathogens is getting the fungicide through the thatch layer. Generally, the thicker the thatch layer, the more impenetrable it is to fungicide movement. Since many of the fungicides used for turfgrass disease control are adsorbed quite readily to thatch, other techniques must be used to get the fungicide into the root zone. This can be accomplished either by aerification prior to the fungicide application, or by applying large amounts of water to leach the fungicide into the root zone.

5.5.6 Fungicide Synergism

Pesticide synergism is when a combination of two pesticides gives better control than would be expected by simply summing the control levels provided by the individual pesticides, analogous to 1+1=3. In cases of additivity, the combination works better than the individual pesticides but only as well as would be predicted by summing the pest control provided by the individual pesticides (1+1=2). And, of course, there is antagonism, which is when the combination of pesticides performs more poorly than would be expected by summing the pest control provided by the individual pesticides (1+1=1). Careful and thorough testing is required to demonstrate synergism, additivity, or antagonism, although funding for such tests is hard to come by.

For many years, the only in-depth source of information on such possible interactions among fungicides in turf has been Houston Couch's excellent and comprehensive reference, "Diseases of Turfgrasses, Third Edition." Recent well-conducted field research in Georgia and Indiana indicates, however, that the fungicide combinations reported in "Diseases of Turfgrasses" to be synergistic against dollar spot perform disappointingly. In this research, out of 108 separate evaluations (fungicide mixture x assessment date) of dollar spot, only three were synergistic.

Recent research does not negate the value of mixing fungicides. Fungicides in mixtures usually do act additively, and mixing fungicides helps to reduce the risk of fungicide resistance. But the latest research raises questions as to the consistency of fungicide synergism (1+1=3) for disease control under field conditions.

5.5.7 Post-Application Irrigation and Fungicide Efficacy

Often, for the control of root diseases on turfgrasses, it is recommended that the fungicide be watered in. This is because most fungicides are not taken up and translocated inside turfgrass plants to turfgrass roots and therefore must be moved into the soil profile to contact pathogens. On the other hand, if they are absorbed and only translocated upward in the plant, some action must be taken to place the fungicide in the root zone and allow the fungicide to reach its intended target. Moving the fungicide through the turf/soil profile with water is usually the method of choice.

No firm recommendations are usually made regarding the amount of water required for optimum fungicide activity. This is because the water status of the soil, the soil type, and the chemical nature of the fungicide all affect how much watering-in should be done.

Little research has been conducted to establish optimum post-irrigation schedules for turfgrass fungicides. However, some general guidelines might be helpful. First, never water in fungicides used for foliar disease control. Studies have shown that if a fungicide applied for foliar disease control is not allowed to dry on the leaf surfaces, there is a significant reduction in its efficacy. For products such as sterol inhibiting fungicides applied for root disease control, the amount of water used to move the fungicide into the root zone should be sufficient also to wet the upper root zone. If the soil is dry to begin with, movement of the water front can be monitored to determine the depth of water penetration. If the soil is already moist, post-spray irrigation should not exceed 1 inch of water. On sandier root zones, this should be reduced to 1/2 inch.

Often times, fungicides applied for root disease control may be applied in excess of 3 gallons of water per 1000 sq. ft. In these cases, a minimal amount of post-irrigation watering is necessary. In all cases, the irrigation should be applied before the fungicide has dried on the foliage.

5.5.8 Monitoring the Results of Fungicide Applications

Detailed monitoring of the results of a fungicide application can shed light on the nature of the problem, point to potential equipment or application failures, effectively assess fungicide efficacy, and provide a means of adjusting fungicide timing or placement for more effective future disease control.

5.5.9 Cost of Control

Determining the cost of a fungicide requires a range of considerations including: price from vendor, cost per ounce, label application rates, application intervals, and cost per day.

Vendor Price Lists. This will include the actual price of the fungicide. Lists will be more useful if they contain size of the product and quantity per unit. Other considerations when selecting a fungicide include availability of other products within the same chemical group, past performance of the fungicide, diseases that the fungicide controls, protection interval, fungicide resistance management and date that the product will be delivered.

Cost per ounce. Convert the price to a cost per ounce by taking the total cost of the product and dividing by the total number of ounces.

Application interval. A key element to consider when purchasing a fungicide is the application interval or how long is the fungicide going to control a particular pathogen.

Table 5.5.2 Cost of controlling diseases in turfgrass.

Product	Rate per 1000 square feet	Application Interval (days)	Cost per ounce	Cost per 1000	Cost per day
Fungicide 1	0.4	28	$42.00	$16.80	$0.60
Fungicide 2	2.0	14	$5.00	$10.00	$0.35
Fungicide 3	10	14	$0.88	$8.80	$0.62

Adapted from www.ca.uky.edu/agc/pubs/ppa/ppa1/ppa1.pdf. *Chemical Control of Turfgrass Disease 2006*. P. Vincelli, and A. J. Powell.

Application rate. Consider labeled rate, disease pressure and disease to control. Many labels include preventative and curative rates.

Cost per day. A valuable indicator to evaluate the cost of a particular fungicide is the cost of control per day. This can be calculated by taking the application rate then multiplying it by the cost of product on a per ounce basis, then dividing the result by the application interval.

5.6 Record Keeping

5.6.1 Reasons for Recordkeeping

There are a number of reasons for developing detailed records of fungicide applications and recording associated site and management factors. Perhaps most importantly, fungicide and other pesticide records are required by state and federal law. These requirements will be described later. Certainly one of the more important reasons for keeping detailed fungicide records is that they provide the only accurate historical record of fungicide applications to specific turfgrass sites. For example, documenting how the fungicide suspension was prepared, the precise rates applied, the weather conditions surrounding the application, and a detailed description of the outcome of the application may point to specific reasons for success or failure of the application as well as how such a control strategy might be improved in the future.

Proper fungicide records also provide a means of mapping important disease problems. Keeping proper records will provide a means of tracking how disease symptoms change in these and potentially new areas with time and with fungicide application. In most cases, disease symptoms tend to appear in the same location year after year. This is due mainly to the fact that few fungicides actually eliminate pathogens from these sites. Rather, they simply stop the pathogen from growing. Some patch- type diseases, for example, tend to show increased patch diameters from year to year. Including this type of information in fungicide records will eventually allow you to map disease symptoms more effectively and establish longer-term trends in control efficacy. Along those same lines, detailed records can help you keep track of other management practices, such as fertilization, irrigation, and cultivation practices, that impact disease severity and the efficacy of fungicide applications.

5.6.2 What Should Be Recorded?

Ideally all of the following items should be recorded in conjunction with any fungicide application. However, this list could be modified to fit your specific needs:

1. The name of the material applied. Include the trade name, formulation, active ingredient (common name), and EPA registration number. This is important for satisfying legal reporting requirements of pesticide usage.
2. Date and time of application. Of particular importance is the time of day, particularly if it varies from the usual application times.
3. The area treated. This should be recorded either in square feet or in acres.
4. The total amount of material applied. Include the intended or measured rate of active ingredient as well as the total amount of material applied to the turf. It is also useful to record the rates of water in which the fungicide was applied. (e.g. gallons/l000 sq. ft.)
5. Tank storage time and pH. It is usually best to apply fungicides immediately after mixing since a number of fungicides degrade with extended storage time in the tank. In cases where the water supply comes from multiple sources, is important routinely to monitor and record the water pH since this too will affect fungicide degradation.
6. The amount of post-application irrigation.
7. The target disease. This information should indicate whether this diagnosis was a personal diagnosis or a clinical diagnosis. It is important to indicate whether the diagnosis was made prior to the fungicide application or after. The date and specific location of sampling and the date of diagnosis also should be recorded.
8. Weather conditions. These should include the conditions prior to the appearance of symptoms and the conditions at the time of application.
9. Apparent results of the application.

5.6.4 Sample Forms

The following pages have sample forms suitable for entering the types of information important to your management records. They include a record for reporting specific fungicide application information, a diagnostic record for reporting information related to disease diagnosis, and a cultural record to keep track of

FUNGICIDE APPLICATION RECORD

GOLF COURSE ____________________

DATE and TIME	HOLE & SECTION (Circle)	FUNGICIDES APPLIED (Trade Name, a.i., formulation)	EPA Reg. #	RATE	AREA TREATED	TOTAL MATERIAL APPLIED	TANK pH and STORAGE TIME	TARGET DISEASE	RESULTS OF APPLICATION
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy			/1000 ft^2 /Acre					
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy			/1000 ft^2 /Acre					
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy			/1000 ft^2 /Acre					
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy			/1000 ft^2 /Acre					
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy			/1000 ft^2 /Acre					

WEATHER NOTES	OTHER NOTES
Date	Cultivation:
Prior to Application:	Irrigation:
At the Time of Application:	Fertilization:
	Other:

DIAGNOSTIC RECORD

GOLF COURSE ______________________________

DATE AND TIME OF PROBLEM APPEARANCE	HOLE & SECTION (Circle)	SPECIFIC LOCATION OF PROBLEM	TYPE OF DIAGNOSIS (onsite/diag. lab)	SAMPLE COLLECTION DATE	DIAGNOSTIC LAB USED	DATE SAMPLE SENT	DIAGNOSIS	RESPONSE TO DIAGNOSIS
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy							
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy							
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy							
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy							
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy							

WEATHER NOTES	OTHER NOTES
Date	Cultivation:
Prior to Symptoms:	Irrigation:
At the Symptom Appearance:	Fertilization:
	Other:

CULTURAL RECORD

GOLF COURSE ______________________________

DATE AND TIME	HOLE & SECTION (Circle)	FERTILIZER APPLIED	RATE OF NITROGEN	RATE OF PHOSPHORUS	RATE OF POTASSIUM	RATE OF OTHER	CULTIVATION	DAILY IRRIGATION SCHEDULE	TURF WETNESS PERIOD	MOWING FREQUENCY
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy									
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy									
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy									
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy									
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Tee, Green, Fwy									

DATE	DAILY MAX. TEMP	DAILY MIN TEMP	DEW POINTS	RAINFALL	SUNNY/CLOUDY

fertilization, irrigation, seeding/sodding practices and other cultivation practices. The formats presented here are only suggestions. The specific arrangement of entries on any given form can and should be modified to fit your specific needs. You should keep in mind that the format of entries in computer databases may differ substantially from these suggested forms but they can be manipulated to be printed in almost any format you wish. A potential advantage of computerized records is that the fungicide, diagnostic, and cultural records can be linked so that data entries in one will simultaneously be entered into another record and each can be accessed simultaneously.

5.7 Product Updates

5.7.1 Plant Defense Activation

There are several new and existing fungicides that are being promoted as able to produce Induced Systemic Resistance (ISR) and Systemic Acquired Resistance (SAR) responses from turf. Products such as the Phosphites, ASM found in Daconil Action, and the mineral oil Civitas are examples. These products do not work by attacking the fungal organism per se, but rather seem to induce a plant response that helps the plant resist the attack. These types of materials will increase over the next several years as the fungicide industry looks to address concerns for toxicity and disease resistance.

5.8 Disease Management

Note: Before using any pesticide, always confirm that the site you plan to treat and the pest you wish to control are listed on the label.

Table 5.8.1 - Disease management options

Note: Before using any pesticide, always confirm that the site you plan to treat and the pest you wish to control are listed on the label.

Disease (pathogens)	Species affected[1]	Seasonal occurrence and conditions favoring disease	Cultural/chemical management factors
Algae (not a true disease)	ALL	**Persistent wet conditions**	Improve irrigation practices, reduce surface organic matter accumulation that leads to sealed soil surface, improve light penetration, avoid persistent use of DMI fungicides known to have growth regulating effects at high temperatures. Use fungicides only in conjunction with proper cultural remedies.
Anthracnose, basal (crown) rot (*Colletotrichum cereale)*	ANNUAL BLUEGRASS, Kentucky bluegrass, fine fescues, bentgrass	**April–October** Cool (55°-70°F) wet, weather. Stressed (not wounded) turf more prone to attack. Following peak seedhead development of AB, extended periods of high temperature and humidity. Bensulide (herbicide) and flutalonil (fungicide) have been show to enhance disease	Avoid N deficiency and drought especially on annual bluegrass. Reduce compaction, limit thatch to less than 0.5 inch. Reduce leaf wetness. Use of azoxystrobin alone has been shown to increase dollar spot. This can be overcome with use of pre-mix or tank-mix combinations with products with dollar spot activity, i.e., Headway. Specifically, studies have shown the importance of fungicide rotation to maximize preventative control. Cultural management studies of putting surfaces have demonstrated the importance of maintaining adequate N, mowing above 0.140”, and rolling to maintain performance. In addition, regular frequent topdressing seems to enhance recovery. Annual bluegrass seedhead suppression with ethephon or mefluidide combined with trinexapac has been shown to reduce disease. Resistant strains are emerging throughout the country to QoI fungicides and thiophanate-methyl. Avoid sequential applications of products to reduce risk of developing resistance.

Table 5.8.1 - Disease management options

Note: Before using any pesticide, always confirm that the site you plan to treat and the pest you wish to control are listed on the label.

Disease (pathogens)	Species affected[1]	Seasonal occurrence and conditions favoring disease	Cultural/chemical management factors
Anthracnose, foliar blight *(Colletotrichum graminicola)*	ANNUAL BLUEGRASS, bentgrass, and fine fescues	**April–October** Warm (over 78°F), wet, humid weather. Severe on plants in compacted, infertile, dry soil and excessive thatch	Maintain adequate fertility, alleviate compaction and limit thatch to less than 0.25 inch. Minimize leaf wetness. Irrigate to prevent heat stress.
Bentgrass Dead Spot (*Ophiospharerel-la agrostis*)	Creeping bentgrass	Only known to occur on sand based putting surfaces and tees on stands less than six years old. Disease becomes active when temps exceed 68 F for a sustained period of time, optimum growth occurs between 77 and 86º. It will often infect previously infected areas	Physically remove infected areas is best cultural control. Urea and nitrate fertilizers and lime have been shown to enhance disease
Brown patch (*Rhizoctonia solani and Rhizoctonia zea*)	All cool season turfgrasses: Kentucky bluegrass, BENTGRASS, RYEGRASS, ANNUAL BLUEGRASS, fine-leaf fescues, TALL FESCUE	**All seasons** Warm conditions (over 75°F) that persist (remain over 60°F) into the evening. Rainy, humid weather with prolonged leaf wetness. Increased severity with excessive N and low P and K. Disease is more severe on low cut turf.	Maintain moderate, balanced fertility. Minimize leaf wetness, alleviate compaction and maintain thatch less than 0.5 inch. Raise mowing height, use tolerant cultivars. Water early in the day and remove dew from greens. The use of organic fertilizers and composts has been shown to reduce disease activity. The use of fans on putting surfaces to minimize leaf wetness has been shown to be effective. Insecticides and herbicides have been shown to enhance disease during stressful conditions. Avoid high rates of DMI fungicides during periods of high temperature due to the known growth regulator effect that can increase problems with algae.
Yellow patch (low temperature brown patch (*Rhizoctonia cerealis)*	Bluegrass, bentgrass, tall fescue (is generally not fatal)	**All seasons** Cool (under 60°F), wet conditions. High N fertility can increase severity.	Balance N, P, K fertility, reduce leaf wetness. Reduce thatch to less than 1 inch. Improve surface drainage. The use of organic fertilizers and composts has been shown to reduce disease activity
Copper spot (*Gloeocercospora sorghi*)	Low-cut bentgrass, Zoysiagrass	**June-October** Warm (68-86 F), wet weather. Excessive N, highly acidic soil.	Limit water soluble N when disease is active especially on *Agrostis canina* –Velvet bentgrass) Do not mow turf when wet. Select resistant varieties. Liming may help on soils with pH at or below 5.5
Damping-off, seed rot (various pathogens)	All grasses	**April-October**	Provide good seedbed and conditions for seedling vigor. Species of Pythium, Fusarium, and Rhizoctonia often cause damping-off. Select fungicides accordingly.
Dollar spot (*Sclerotinia homoeocarpa)* **Dollar spot** (*Sclerotinia homoeocarpa)*	All cool season grasses especially ANNUAL BLUEGRASS and BENTGRASS	**June–October** Warm days (60°-90°F) and cool nights (over 50°F). Prolonged leaf wetness, dew and high humidity. Dry soils with low N fertility.	Avoid N deficiency, drought and night watering. Reduce compaction and limit thatch to less than 0.5 inch. Minimize leaf wetness, use tolerant cultivars. The use of organic fertilizers and composts has been shown to reduce disease severity depending on host susceptibility. For example, dollar spot resistant varieties such as L-93 and Declaration creeping bentgrass do not benefit from organic fertilizer use. Early AM mowing and aggressive dew removal with rolling on putting surfaces and fairway turf has been shown to reduce disease. Regular use of paclobutrazol PGR allows for 20 to 25 percent reduction in fungicide rate. Current research is demonstrating the effectiveness of early season applications of Vinclozolin to reduce inoculum and thereby reducing overall disease pressure during the season, however this method does not appear to reduce the severity of late-season dollar spot infestations from September through October.

Table 5.8.1 - Disease management options

Note: Before using any pesticide, always confirm that the site you plan to treat and the pest you wish to control are listed on the label.

Disease (pathogens)	Species affected[1]	Seasonal occurrence and conditions favoring disease	Cultural/chemical management factors
Fairy rings (various fungi)	All cool season grasses	**April-October** Cool (45°-60°F) and adequate soil moisture favor activity.	Irrigate to prevent drought stress. Mask symptoms by removal of cores, thorough watering, and moderate fertility. In critical areas, remove the soil and reseed or renovate. Irrigate prior to fungicide application. Studies have found that water injection cultivation in association with wetting agents and fungicides enhances control.
Gray leafspot (*Pyricularia grisea*)	Perennial Ryegrass and fescues	**June-August** Warm, wet weather.	Avoid prolonged leaf wetness. Avoid ryegrasses and fescues if possible. Avoid late summer ryegrass overseeding in areas prone to GLS. Avoid excessive reliance on QoI fungicides as they have been shown to increase risk of developing resistance. High label rate of *[NY]Prograss herbicide has been shown to increase GLS.
Leaf blight *(Ascochyta spp., Leptosphaerulina spp.)*	All cool season turfgrasses, especially KENTUCKY BLUEGRASS, BENTGRASS, FINE-LEAF FESCUES	**April-October** Warm (60°-80°F), humid conditions. Disease is more severe on stressed turf, newly sodded areas, and on turf following grass herbicide applications.	Avoid excess N (especially in spring) and night watering. Use resistant varieties of Kentucky bluegrass, perennial ryegrass, and fine fescue. Raise mowing height. Maintain adequate fertility; mow at species recommended height when turf is dry. Minimize leaf wetness. Avoid herbicide applications or sodding when extended periods of hot, humid weather is expected.
Leaf spots (*Drechslera spp., Bipolaris spp.,Curvularia spp.*)	Kentucky bluegrass, PERENNIAL RYEGRASS, fescues	**April-October** Cool to warm (40°-80°F), moist, wet weather. Wind, equipment, animals and people easily spread diseases.	Use resistant cultivars of tall fescue and Kentucky bluegrass. Maintain moderate fertility but avoid excessive growth. Water to avoid drought stress. Mow at recommended height when turf is dry. Triadimefon may increase disease.
Necrotic ringspot *(Ophiosphaerella korrae, formerly Leptosphaeria korrae)*	KENTUCKY BLUEGRASS, fine fescues, ANNUAL BLUEGRASS, bentgrass	**June-September** Growth stimulated by cool to warm (50°-75°F), wet weather. Symptoms exacerbated by stress, compaction, drought and high temperatures (over 80°F). Excessive N applications (greater than 0.5 pound/ 1000 square feet) increase severity. Disease is most prevalent on 2-4 year old turf.	Avoid excessive water-soluble N applications. Irrigate to reduce stress. Increase mowing height, reduce compaction and thatch (less than 0.5 inch). Use tolerant cultivars. Mix perennial ryegrass into Kentucky bluegrass. Studies have shown that when turf is infected light, frequent watering can promote survival of the compromised root system. Applications of chlorothalonil may increase disease pressure.
Microdochium patch (also known as pink snow mold or Fusarium patch) *(Microdochium nivale)*	All cool season grasses, especially Perennial Ryegrass and annual bluegrass and creeping bentgrass	**March-June and September-November** Cool (32°-50°F), wet weather favors activity. Severe damage under heavy, wet snow on unfrozen ground (snow is not necessary).	Use moderate N during late summer and fall to avoid excessive late season growth. Prevent snow compaction and use snow fences to prevent drifting snow. Use resistant varieties. Rake matted grass in spring. Can be smeared by mowing or move with drainage patterns. Avoid Ca applications in the late season and keep K applications to a minimum throughout the year as excess Ca and K have been associated with increased disease.
Powdery mildew (*Blumeria graminis* formerly *Erysiphe graminis*)	KENTUCKY BLUEGRASS, fine fescues	**July-September** Cool (55°-72°F), wet weather. Disease is more severe in shaded areas and areas where air circulation is poor.	Avoid excess N and shade. Improve light penetration and air circulation. Use shade tolerant cultivars.

Table 5.8.1 - Disease management options

Note: Before using any pesticide, always confirm that the site you plan to treat and the pest you wish to control are listed on the label.

Disease (pathogens)	Species affected[1]	Seasonal occurrence and conditions favoring disease	Cultural/chemical management factors
Pythium blight (*Pythium* spp.)	Kentucky bluegrass, RYEGRASS, tall fescue, annual bluegrass, bentgrass, fine-leaf fescues	**July-August** High temperatures (over 90°F) and humidity that persist into the evening (temperatures over 70°F and relative humidity greater than 70°F). Prolonged leaf wetness. Poor drainage and thatchy turf. Spread by free water (may follow a drainage pattern) on clippings, equipment and shoes. Excessive N fertility and low pH can increase severity and incidence.	Maintain moderate N and pH in optimum range. Improve drainage, minimize leaf wetness. Avoid mowing and trafficking susceptible turf when fungal threads are present. Use fungicide treated seed when planting in hot, humid weather.
Pythium root rot (*Pythium* spp.)	All cool season turfgrasses	**March-November** Cool (32°-60°F), wet conditions. Low light, high traffic and low mowing heights.	Avoid excessive springtime N applications, prolonged wet conditions and excess watering. Improve drainage, increase light and raise mowing height. Avoid frequent applications of broad-spectrum systemic fungicides. The use of some composts and organic fertilizers has been shown to reduce disease severity.
Red Thread (*Laetisaria fuciformis*)	Kentucky bluegrass, annual bluegrass, PERENNIAL RYEGRASS, FINE FESCUES, bentgrass	**May-October** Cool, (40°-70°F) wet conditions favor activity. Often found along with Pink patch. Pathogen is spread by running water, people, equipment and animals.	Avoid N deficiency, especially on perennial ryegrass and fescue. Promote active growth, reduce leaf wetness and irrigate to prevent stress. Moderately resistant cultivars are available.
Pink patch *(Limonomyces roseipellis)*	Kentucky bluegrass, annual bluegrass, PERENNIAL RYEGRASS, FINE FESCUES, bentgrass	**May-October** Cool (50°-75°F) wet, weather favors activity. Often found on the same plant as Red thread.	Fungicide treatment is rarely recommended. Maintain adequate and balanced fertility (avoid N deficiency especially on perennial ryegrass and fescue). Reduce leaf wetness. Increase air circulation where possible. The use of some organic fertilizers will reduce disease severity. Moderately resistant cultivars are available.
Rusts (*Puccinia* spp.)	All cool season turfgrasses, especially Perennial Ryegrass	**July-October** Warm nights (68°-86°F) and wet leaves. Most severe mid- to late summer into fall when turf is not actively growing or is under stress.	Maintain fertility for active growth throughout the season. Minimize leaf wetness. Irrigate to prevent drought stress. Use tolerant cultivars.
Smuts (most commonly Stripe smut, *Ustilago* spp., *Urocystis* spp.)	KENTUCKY BLUEGRASS, creeping bentgrass, colonial bentgrass	**April–November** Infection occurs during cool (50°-65°F) wet conditions. Excessive leaf wetness and low to moderate soil moisture.	Fertilize moderately but not excessively as excessive N has been shown to increase severity. Irrigate to avoid drought stress. Minimize leaf wetness. Use tolerant cultivars.
Summer patch (*Magnaporthe poae*) **Summer patch** (*Magnaporthe poae*)	KENTUCKY BLUEGRASS, fine fescues, ANNUAL BLUEGRASS, bentgrass	**June-September** Hot days (over 85°F) that persist into evening (remain over 60°F) and rainy conditions. Infection in late spring when soil temperatures (over 65°F) and symptoms appear in the summer. Spread by dethatching, cultivation equipment and infected sod. Severe during hot, wet years on poorly drained, compacted sites. Quick release N fertilizers may cause severe disease. Frequent watering, a pH greater than 5.5 and	Maintain adequate fertility with pH at 6.0. Improve drainage and irrigate to prevent heat stress. Avoid excess N, drought and excess water. Alleviate compaction and increase height of cut. Studies have shown that spring applications of ammonium sulfate or other acidifying fertilizers can reduce disease. Preventative applications in the spring require multiple high rate applications of DMI fungicides as a soil drench when soil temperature reaches 65°F at a 2-inch depth All fungicides used to control disease should be applied in high volumes of water insure placement in the root system. Renovate with resistant bluegrass or ryegrass varieties.

Table 5.8.1 - Disease management options

Note: Before using any pesticide, always confirm that the site you plan to treat and the pest you wish to control are listed on the label.

Disease (pathogens)	Species affected[1]	Seasonal occurrence and conditions favoring disease	Cultural/chemical management factors
		low mowing heights may increase severity. Can be confused with heat stress, insect damage or other diseases.	
Take-all patch (*Gaeumanno-myces graminis*)	BENTGRASS	**March-June and September-November** Infection occurs in cool (65°F), wet weather. Symptoms appear in warm to hot temperatures (over 70°F) and dry weather. Disease can be spread by mechanical equipment, infected sod or seed. Prevalent on moist, high pH and nutritionally unbalanced soils (liming enhances the disease). Soil conditions favoring disease are coarse texture, low organic content, recently fumigated or high sand content.	Apply acidifying fertilizers to reduce thatch pH (care should be taken at high temperatures to avoid fertilizer burn) but avoid liming. Maintain adequate N fertility, improve drainage and alleviate compaction. Avoid heavy, frequent irrigation especially with high pH water. The use of composts and organic fertilizers may reduce the severity of Take-all in newly seeded areas. Applications of manganese-and copper-containing fertilizers have been shown to reduce disease. Studies have shown that spring applications of ammonium sulfate or other acidifying fertilizers can reduce disease.
Typhula blight (also known as Gray snow mold) (*Typhula* spp.)	Kentucky bluegrass, BENTGRASS, ANNUAL BLUEGRASS, TALL FESCUE, fine fescues and Perennial Ryegrass	**December-April** Cold temperatures (32°-45°F) and prolonged snow cover. Heavy straw mulches, tree leaves, and a tall turf canopy. High applications of soluble N before growth ceases in late fall.	Avoid applications of N after October 1 until the top growth ceases to prevent lush turf going into winter. Increase drainage. Prevent compaction of snow and use snow fences or barriers to prevent drifts. Melt snow with darkening agent such as organic fertilizer or compost. In spring rake the affected turf, remove debris, lightly fertilize and reseed with a soil/seed patch mixture. Disease occurrence and severity may be reduced by applying heavy rates of compost over dormant turf and removing excess compost in early spring before turf resumes growth. Avoid Ca applications in the late season and keep K applications to a minimum throughout the year as excess Ca and K have been associated with increased disease.
Waitea Patch *(Waitea circinata)*	annual bluegrass, creeping bentgrass	**High risk April to June and Sept and October** Cool (40°-70°F) wet weather. Pathogen needs free water (poorly drained, over irrigated) to spread. New plantings are most susceptible and high N can increase severity.	Maintain active not lush growth. Avoid excess N, but N fertilization has shown to reduce severity.
Yellow tuft (Downy mildew) *(Sclerophthora macrophoma)*	Bluegrass, bentgrass and tall fescue	**High risk April to June and Sept and October** Cool (40°-70°F) wet weather. Pathogen needs free water (poorly drained, over irrigated) to spread. New plantings are most susceptible and high N can increase severity.	Maintain active not lush growth. Avoid excess N. Mask symptoms by applying 1 ounce of iron sulfate per 1000 square feet every 2-4 weeks. Improve drainage, reduce leaf wetness, reduce or alleviate compaction.

5.9 Disease treatment options

Table 5.9.1 – Pesticides labeled for treatment of Algae

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
chlorothalonil (Daconil Ultrex Turf Care)	1.8-5.03 oz/1000 sq ft	3.5	12	M5	151 - 423	See label for specific setback distances from water bodies.
chlorothalonil (Pegasus DFX)	1.82-3.25 oz/1000 sq ft	3.5	12	M5	153 - 273	See label for specific setback distances from water bodies.
chlorothalonil (Anderson's Golf Products 5% Daconil)	1.9-5.2 lbs/1000 sq ft	3.5	-	M5	155 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research.
*NY mancozeb (Fore 80 WP Rainshield)	6 oz/1000 sq ft	3	24	M3	336	Not for use on sod farms, athletic fields and residential turf.
*NY mancozeb, copper hydroxide (Junction)	2-3.6 oz/1000 sq ft	4	48	M3 + M1	104 - 188	On sod farms, harvesting of treated turf is prohibited until 5 days following application.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
*NY - Restricted-use pesticide in New York State.

Table 5.9.2 – Pesticides labeled for Anthracnose, basal (crown) rot and foliar blight

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	3	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	3	4	11	7 - 13	
Bacillus licheniformis SB3086 , indole-3-butyric acid (Roots Ecoguard)	20 fl oz/1000 sq ft	L	4	NC + NC	Not Available	
Bacillus subtilis GB03 (Companion Liquid Biological Fungicide)	4-6 fl oz/1000 sq ft	L	4	F6	Not Available	
chlorothalonil (Pegasus DFX)	3.25-5 oz/1000 sq ft	3	12	M5	273 - 420	See label for specific setback distances from water bodies. Rate range depends on application interval; see label.

Table 5.9.2 – Pesticides labeled for Anthracnose, basal (crown) rot and foliar blight

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
chlorothalonil (Daconil Ultrex Turf Care)	2.75-5.03 oz/1000 sq ft	3	12	M5	231 - 423	See label for specific setback distances from water bodies. Rate range depends on application interval; see label.
chlorothalonil (Anderson's Golf Products 5% Daconil)	2.8-5.2 lbs/1000 sq ft	3	-	M5	228 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	3-5.4 fl oz/1000 sq ft	-	12	M5 + P1	172 - 309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application interval; see label.
*NY chlorothalonil, propiconazole, fludioxonil (Instrata)	2.75-6.0 fl oz/1000 sq ft	-	12	M5 + 3 + 12	101 - 220	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
*NY †fludioxonil (Medallion)	0.25-0.5 oz/1000 sq ft	2.5	12	12	8 - 16	
*NYΔ myclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	2	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
Polyoxin D zinc salt (Endorse)	11 lb/acre	3	4	19	7	Not for use on turf grown for commercial seed production. Aids in control.
Pseudomonas aureofaciens str Tx-1 (Spot-less Biofungicide)	0.73-1.47 fl oz/1000 sq ft	L	-	NC	Not Available	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.55-1.1 oz/1000 sq ft	-	-	11 + 7	11 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	2	12	1	111 - 167	Basal rot rates.
*NY thiophanate-methyl (3336F)	2-4 fl oz/1000 sq ft	2	12	1	56 - 111	Foliar blight rates.

Table 5.9.2 – Pesticides labeled for Anthracnose, basal (crown) rot and foliar blight

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	1.5	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.
tryfloxystrobin (Compass)	0.15-0.25 oz/1000 sq ft	3.5	12	11	6 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	-	12	11 + 3	22 - 56	
Δtryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.3 – Pesticides labeled for Bentgrass Dead Spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
boscalid (Emerald)	0.18 oz/1000 sq ft	L	-	7	9	For use on golf course turfgrass only.
*NY†fludioxonil (Medallion)	0.3-0.5 oz/1000 sq ft	L	12	12	10 - 16	
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.55-1.1 oz/1000 sq ft	-	-	11 + 7	11 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	L	12	1	111 - 167	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.4 – Pesticides labeled for Brown patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	3 to 4	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	3 to 4	4	11	7 - 13	
Bacillus licheniformis SB3086 , indole-3-butyric acid (Roots Ecoguard)	20 fl oz/1000 sq ft	2	4	NC + NC	Not Available	Aids in suppression of brown patch.
Bacillus subtilis GB03 (Companion Liquid Biological Fungicide)	4-6 fl oz/1000 sq ft	1	4	F6	Not Available	
Bacillus subtilis str QST 713 (Rhapsody)	2-10 fl oz/1000 sq ft	1	4	F6	Not Available	
chlorothalonil (Pegasus DFX)	1.82-3.25 oz/1000 sq ft	3	12	M5	153 - 273	See label for specific setback distances from water bodies.
chlorothalonil (Daconil Ultrex Turf Care)	1.8-5.03 oz/1000 sq ft	3	12	M5	151 - 423	See label for specific setback distances from water bodies. Rate range depends on application timing and interval; see label.
chlorothalonil (Anderson's Golf Products 5% Daconil)	1.9-5.2 lbs/1000 sq ft	3	-	M5	155 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	2-3.5 fl oz/1000 sq ft	-	12	M5 + P1	114 - 200	See label for where this product can be used. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
chlorothalonil, propiconazole (Concert II)	3-8.3 fl oz/1000 sq ft	-	12	M5 + 3	130 - 360	See label for where this product can be used. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
*NY chlorothalonil, propiconazole, fludioxonil (Instrata)	2.75-6.0 fl oz/1000 sq ft	-	12	M5 + 3 + 12	101 - 220	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated with prior to harvest

Table 5.9.4 – Pesticides labeled for Brown patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
						must be mechanically cut, rolled and harvested.
*NY†fludioxonil (Medallion)	0.2-0.5 oz/1000 sq ft	3	12	12	6 - 16	Rate range depends on application interval; see label.
*NYiprodione (26GT Fungicide)	3-4 fl oz/1000 sq ft	3	24	2	48 - 64	Use of this product at residential sites is prohibited.
*NYiprodione (Anderson's Golf Products Fungicide X)	4.8-7.21 lbs/1000 sq ft	3	-	2	66 - 99	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Use of this product at residential sites is prohibited. Label lists specific rate depending on timing and disease pressure.
*NYmancozeb (Fore 80 WP Rainshield)	4 oz/1000 sq ft	3	24	M3	224	Not for use on sod farms, athletic fields and residential turf.
*NYmancozeb, copper hydroxide (Junction)	2-3.6 oz/1000 sq ft	L	48	M3 + M1	104 - 188	On sod farms, harvesting of treated turf is prohibited until 5 days following application.
metconazole (Tourney)	0.28-0.37 oz/1000 sq ft	3	12	3	9 - 12	
*NYΔmyclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	2.5	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
Polyoxin D zinc salt (Endorse)	11 lb/acre	3	4	19	7	Not for use on turf grown for commercial seed production.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.55-1.1 oz/1000 sq ft	-	-	11 + 7	11 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	2-4 fl oz/1000 sq ft	2.5	12	1	56 - 111	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	2	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.
Trichoderma harzianum Rifai T-22, Trichoderma virens str G-41 (Turfshield Plus G)	1-4 lbs/1000 sq ft	-	4	NC + NC	Not Available	
Trichoderma harzianum Rifai T-	0.5-1.5 oz/1000 sq ft	-	4	NC + NC	Not Available	

Table 5.9.4 – Pesticides labeled for Brown patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
22, Trichoderma virens str G-41 (Turfshield Plus WP)						
tryfloxystrobin (Compass)	0.15-0.25 oz/1000 sq ft	4	12	11	6 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	2	12	11 + 3	22 - 56	
Δtryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	2	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.5 – Pesticides labeled for Copper spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
chlorothalonil (Daconil Ultrex Turf Care)	3.7-5.03 oz/1000 sq ft	L	12	M5	311 - 423	See label for specific setback distances from water bodies.
chlorothalonil (Pegasus DFX)	3.25-5 oz/1000 sq ft	L	12	M5	273 - 420	See label for specific setback distances from water bodies.
chlorothalonil (Anderson's Golf Products 5% Daconil)	3.8-5.2 lbs/1000 sq ft	L	-	M5	310 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Rate depends on application timing.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	4-5.4 fl oz/1000 sq ft	-	12	M5 + P1	229 - 309	Sod farm turf treated with chlorothalonil prior to harvest must be mechanically cut, rolled and harvested.
*NYmancozeb (Fore 80 WP Rainshield)	4-8 oz/1000 sq ft	L	24	M3	224 - 448	Not for use on sod farms, athletic fields and residential turf.
*NYmancozeb, copper hydroxide (Junction)	2-3.6 oz/1000 sq ft	L	48	M3 + M1	104 - 188	On sod farms, harvesting of treated turf is prohibited until 5 days following application.
*NYΔmyclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	L	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more

Table 5.9.5 – Pesticides labeled for Copper spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
						than 3.43 fl oz of product per 1000 sq ft per year.
*NY thiophanate-methyl (3336F)	2-4 fl oz/1000 sq ft	L	12	1	56 - 111	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	L	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.6 - Pesticides labeled for Damping-off, seed rot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
mefenoxam (Subdue Maxx)	0.5-1 fl oz/1000 sq ft	-	48	4	6 - 12	Apply as a soil surface spray in 1 to 5 gals. of water immediately after seeding.
Polyoxin D zinc salt (Endorse)	11 lb/acre	-	4	19	7	Not for use on turf grown for commercial seed production. Labeled for Rhizoctonia damping off. Aids in control.
propamocarb hydrochloride (Banol)	1 1/3-4 fl oz/1000 sq ft	-	24	28	15 - 180	Apply after seedling germination for control.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 5.9.7 – Pesticides labeled for Dollar Spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
Bacillus licheniformis SB3086 , indole-3-butyric acid (Roots Ecoguard)	20 fl oz/1000 sq ft	2	4	NC + NC	Not Available	
Bacillus subtilis GB03 (Companion Liquid Biological Fungicide)	4-6 fl oz/1000 sq ft	1	4	F6	Not Available	
boscalid (Emerald)	0.13-0.18 oz/1000 sq ft	3.5	-	7	7 - 9	For use on golf course turfgrass only.
chlorothalonil (Daconil Ultrex Turf Care)	1-5.03 oz/1000 sq ft	3	12	M5	84 - 423	See label for specific setback distances from water bodies. Rate range depends on application timing and interval; see label.
chlorothalonil (Pegasus DFX)	1.8-3.25 oz/1000 sq ft	3	12	M5	151 - 273	See label for specific setback distances from water bodies.
chlorothalonil (Anderson's Golf Products 5% Daconil)	1.0-5.2 lbs/1000 sq ft	3	-	M5	82 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Rate depends on application timing.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	1-5.4 fl oz/1000 sq ft	-	12	M5 + P1	57 - 309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
chlorothalonil, propiconazole (Concert II)	1.5-8.3 fl oz/1000 sq ft	-	12	M5 + 3	65 - 360	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
[*NY]chlorothalonil, propiconazole, fludioxonil (Instrata)	2.75-7.0 fl oz/1000 sq ft	-	12	M5 + 3 + 12	101 - 257	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
[*NY]mancozeb (Fore 80 WP Rainshield)	6-8 oz/1000 sq ft	1	24	M3	336 - 448	Not for use on sod farms, athletic fields and residential turf.
[*NY]mancozeb, copper hydroxide (Junction)	2-3.6 oz/1000 sq ft	L	48	M3 + M1	104 - 188	On sod farms, harvesting of treated turf is prohibited until 5 days following application.
metconazole (Tourney)	0.18-0.37 oz/1000 sq ft	4	12	3	6 - 12	

Table 5.9.7 – Pesticides labeled for Dollar Spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NYΔmyclobutanil (Eagle 20 EW)	0.5-2.4 fl oz/1000 sq ft	4	24	3	7 - 32	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year. Rate range depends on application timing and interval; see label.
Pseudomonas aureofaciens str Tx-1 (Spot-less Biofungicide)	0.73-1.47 fl oz/1000 sq ft	-	-	NC	Not Available	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.83-1.1 oz/1000 sq ft	-	-	11 + 7	17 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	2-4 fl oz/1000 sq ft	4	12	1	56 - 111	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	4	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.
Trichoderma harzianum Rifai T-22, Trichoderma virens str G-41 (Turfshield Plus G)	1-4 lbs/1000 sq ft	1	4	NC + NC	Not Available	
Trichoderma harzianum Rifai T-22, Trichoderma virens str G-41 (Turfshield Plus WP)	0.5-1.5 oz/1000 sq ft	1	4	NC + NC	Not Available	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	-	12	11 + 3	22 - 56	
Δtryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.8 – Pesticides labeled for Fairy ring

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.4 oz/1000 sq ft	3	4	11	15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	3	4	11	13	
flutolanil (ProStar 70 WP)	2.2-4.5 oz/1000 sq ft	3	12	7	97 - 198	See label for specific setback distance restrictions from water bodies.
metconazole (Tourney)	0.37 oz/1000 sq ft	3	12	3	12	
Polyoxin D zinc salt (Endorse)	4 oz/1000 sq ft	2.5	4	19	7	Not for use on turf grown for commercial seed production. Suppression and short term control.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	1.1 oz/1000 sq ft	-	-	11 + 7	22	For use on golf course turfgrass only. See label for specific resistance management requirements.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 5.9.9 – Pesticides labeled for Gray Leaf Spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	2-5.4 fl oz/1000 sq ft	-	12	M5 + P1	114 - 309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate depends on application timing.
chlorothalonil, propiconazole (Concert II)	3-8.3 fl oz/1000 sq ft	3	12	M5 + 3	130 - 360	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
metconazole (Tourney)	0.37 oz/1000 sq ft	2	12	3	12	
*NYΔmyclobutanil (Eagle 20 EW)	1.2-2.4 fl oz/1000 sq ft	-	24	3	16 - 32	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year. Rate range depends on application timing and interval; see label.
Polyoxin D zinc salt (Endorse)	11 lb/acre	1	4	19	7	Not for use on turf grown for commercial seed production. Suppression and short term control. Aids in suppression.

Table 5.9.9 – Pesticides labeled for Gray Leaf Spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	4	12	1	111 - 167	
tryfloxystrobin (Compass)	0.15-0.25 oz/1000 sq ft	3	12	11	6 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	-	12	11 + 3	22 - 56	
Δtryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.10 – Pesticides labeled for Leaf spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	-	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	-	4	11	7 - 13	
chlorothalonil (Daconil Ultrex Turf Care)	1.8-5.03 oz/1000 sq ft	-	12	M5	151 - 423	See label for specific setback distances from water bodies. Rate range depends on application timing and interval; see label.
chlorothalonil (Pegasus DFX)	1.8-3.25 oz/1000 sq ft	-	12	M5	151 - 273	See label for specific setback distances from water bodies.
chlorothalonil (Anderson's Golf Products 5% Daconil)	1.9-5.2 lbs/1000 sq ft	-	-	M5	155 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Rate depends on application timing.
chlorothalonil, propiconazole (Concert II)	3-8.3 fl oz/1000 sq ft	-	12	M5 + 3	130 - 360	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.

Table 5.9.10 – Pesticides labeled for Leaf spot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NY chlorothalonil, propiconazole, fludioxonil (Instrata)	2.75-6.0 fl oz/1000 sq ft	-	12	M5 + 3 + 12	101 - 220	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. See label for other rate restrictions. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
*NY iprodione (Anderson's Golf Products Fungicide X)	2.4-7.21 lbs/1000 sq ft	-	-	2	33 - 99	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Use of this product at residential sites is prohibited. Label lists specific rate depending on timing and disease pressure.
*NY iprodione (26GT Fungicide)	3-4 fl oz/1000 sq ft	-	24	2	48 - 64	Use of this product at residential sites is prohibited.
*NYΔ myclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	-	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
Polyoxin D zinc salt (Endorse)	11 lb/acre	-	4	19	7	Not for use on turf grown for commercial seed production. Aids in control.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.55-1.1 oz/1000 sq ft	-	-	11 + 7	11 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	-	12	1	111 - 167	
tryfloxystrobin (Compass)	0.15-0.25 oz/1000 sq ft	-	12	11	6 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	-	12	11 + 3	22 - 56	
Δ tryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - Measure of potential toxicity risk of a pesticide application
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.11 – Pesticides labeled for Pink Snow Mold (Microdochium or fusarium patch)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.4 oz/1000 sq ft	2.5	4	11	15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	2.5	4	11	13	
chlorothalonil (Daconil Ultrex Turf Care)	5.03 oz/1000 sq ft	2.5	12	M5	423	See label for specific setback distances from water bodies.
chlorothalonil (Anderson's Golf Products 5% Daconil)	5.2 lbs/1000 sq ft	2.5	-	M5	424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research.
chlorothalonil, propiconazole (Concert II)	5.5-8.3 fl oz/1000 sq ft	-	12	M5 + 3	239 - 360	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
*NY chlorothalonil, propiconazole, fludioxonil (Instrata)	5-11 fl oz/1000 sq ft	-	12	M5 + 3 + 12	183 - 404	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
*NY †fludioxonil (Medallion)	0.5 oz/1000 sq ft	4	12	12	16	
*NY iprodione (26GT Fungicide)	8 fl oz/1000 sq ft	3	24	2	128	Use of this product at residential sites is prohibited.
*NY mancozeb (Fore 80 WP Rainshield)	6-8 oz/1000 sq ft	2	24	M3	336 - 448	Not for use on sod farms, athletic fields and residential turf.
metconazole (Tourney)	0.37-0.44 oz/1000 sq ft	L	12	3	12 - 14	
*NYΔ myclobutanil (Eagle 20 EW)	1.2-2.4 fl oz/1000 sq ft	2	24	3	16 - 32	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year. Rate range depends on application timing and interval; see label.
Polyoxin D zinc salt (Endorse)	11 lb/acre	L	4	19	7	Not for use on turf grown for commercial seed production. Aids in control.

Table 5.9.11 – Pesticides labeled for Pink Snow Mold (Microdochium or fusarium patch)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.55-1.1 oz/1000 sq ft	-	-	11 + 7	11 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	2-4 fl oz/1000 sq ft	3	12	1	56 - 111	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	3-6 lbs/1000 sq ft	2	12	3	35 - 70	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.
Trichoderma harzianum Rifai T-22, Trichoderma virens str G-41 (Turfshield Plus WP)	0.5-1.5 oz/1000 sq ft	-	4	NC + NC	Not Available	
tryfloxystrobin (Compass)	0.25 oz/1000 sq ft	3	12	11	10	
*NY tryfloxystrobin, triadimefon (Armada)	1.2-1.5 oz/1000 sq ft	-	12	11 + 3	45 - 56	
Δtryfloxystrobin, triadimefon (Tartan)	2 fl oz/1000 sq ft	-	12	11 + 3	39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - Measure of potential toxicity risk of a pesticide application
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.12 – Pesticides labeled for Necrotic ringspot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	L	4	11	7 - 15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	L	4	11	13	
*NY iprodione (26GT Fungicide)	8 fl oz/1000 sq ft	2	24	2	128	Use of this product at residential sites is prohibited.
*NYΔ myclobutanil (Eagle 20 EW)	1.2-2.4 fl oz/1000 sq ft	3	24	3	16 - 32	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	1.1 oz/1000 sq ft	-	-	11 + 7	22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	2	12	1	111 - 167	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - Measure of potential toxicity risk of a pesticide application
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.13 – Pesticides labeled for Pink patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	-	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	-	4	11	7 - 13	
tryfloxystrobin (Compass)	0.1-0.25 oz/1000 sq ft	-	12	11	4 - 10	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 5.9.14 – Pesticides labeled for Powdery mildew

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
Bacillus subtilis str QST 713 (Rhapsody)	2-10 fl oz/1000 sq ft	L	4	F6	Not Available	
*NYΔmyclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	4	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	4	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - Measure of potential toxicity risk of a pesticide application
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.15 – Pesticides labeled for Pythium blight

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	2	4	11	7 - 15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	2	4	11	13	
Bacillus subtilis GB03 (Companion Liquid Biological Fungicide)	4-6 fl oz/1000 sq ft	-	4	F6	Not Available	
*NYetridiazole (Terrazole 35% WP)	2-4 oz/1000 sq ft	1	12	14	44 - 88	Application is limited to tees and greens. Application to fairways is prohibited. For commercial use only. Not for use on home lawns, sod farms or municipal parks.
fostetyl-Al (Aliette WDG Brand)	4-8 oz/1000 sq ft	2.5	12	33	105 - 209	
fostetyl-Al (Lesco Prodigy Signature)	4-8 oz/1000 sq ft	2.5	12	33	105 - 209	
mefenoxam (Subdue Maxx)	0.5-1 fl oz/1000 sq ft	3	48	4	6 - 12	Apply as a soil surface spray in 1 to 5 gals. of water immediately after seeding. Also for use on established turf.

Table 5.9.15 – Pesticides labeled for Pythium blight

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
mono and di-potassium salts of phosphorus acid (Riverdale Magellan)	4.1-8.2 fl oz/1000 sq ft	-	4	33	Not Available	
propamocarb hydrochloride (Banol)	1 1/3-4 fl oz/1000 sq ft	2.5	24	28	15 - 180	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
*NY - Restricted-use pesticide in New York State.

Table 5.9.16 – Pesticides labeled for Pythium root rot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	2	4	11	7 - 15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	2	4	11	13	
*NYetridiazole (Terrazole 35% WP)	2-4 oz/1000 sq ft	1	12	14	44 - 88	Application is limited to tees and greens. Application to fairways is prohibited. For commercial use only. Not for use on home lawns, sod farms or municipal parks. Apply fungicides October-November for early spring control.
fostetyl-Al (Aliette WDG Brand)	4-8 oz/1000 sq ft	1	12	33	105 - 209	Fosetyl-al can be applied as a spray. Apply fungicides October-November for early spring control. Rates depend on application interval.
fostetyl-Al (Lesco Prodigy Signature)	4-8 oz/1000 sq ft	1	12	33	105 - 209	Fosetyl-al can be applied as a spray. Apply fungicides October-November for early spring control. Rate range depends on application interval; see label.
propamocarb hydrochloride (Banol)	1 1/3-4 fl oz/1000 sq ft	1.5	24	28	15 - 180	Product must be thoroughly watered in.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	1.1 oz/1000 sq ft	-	-	11 + 7	22	For use on golf course turfgrass only. See label for specific resistance management requirements.

Table 5.9.16 – Pesticides labeled for Pythium root rot

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
Trichoderma harzianum Rifai T-22, Trichoderma virens str G-41 (Turfshield Plus G)	1-4 lbs/1000 sq ft	-	4	NC + NC	Not Available	
Trichoderma harzianum Rifai T-22, Trichoderma virens str G-41 (Turfshield Plus WP)	0.5-1.5 oz/1000 sq ft	-	4	NC + NC	Not Available	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
*NY - Restricted-use pesticide in New York State.

Table 5.9.17 – Pesticides labeled for Red Thread

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	4	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	4	4	11	7 - 13	
chlorothalonil (Daconil Ultrex Turf Care)	1.8-5.03 oz/1000 sq ft	3	12	M5	151 - 423	See label for specific setback distances from water bodies. Rate range depends on application timing and interval; see label.
chlorothalonil (Pegasus DFX)	3.25-5 oz/1000 sq ft	3	12	M5	273 - 420	See label for specific setback distances from water bodies. Rate range depends on application interval; see label.
chlorothalonil (Anderson's Golf Products 5% Daconil)	1.9-5.2 lbs/1000 sq ft	3	-	M5	155 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Rate depends on application timing.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	2-5.4 fl oz/1000 sq ft	-	12	M5 + P1	114 - 309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
flutolanil (ProStar 70 WP)	1.5 oz/1000 sq ft	4	12	7	66	

Table 5.9.17 – Pesticides labeled for Red Thread

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NY iprodione (26GT Fungicide)	4 fl oz/1000 sq ft	3.5	24	2	64	Use of this product at residential sites is prohibited.
*NY mancozeb (Fore 80 WP Rainshield)	4-8 oz/1000 sq ft	2	24	M3	224 - 448	Not for use on sod farms, athletic fields and residential turf.
*NY Δ myclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	2	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
Polyoxin D zinc salt (Endorse)	11 lb/acre	4	4	19	7	Not for use on turf grown for commercial seed production. Aids in control.
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	3	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.
tryfloxystrobin (Compass)	0.15-0.25 oz/1000 sq ft	L	12	11	6 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	-	12	11 + 3	22 - 56	
Δ tryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.18 – Pesticides labeled for Rusts

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	4	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	4	4	11	7 - 13	See label for specific rust species.
Bacillus subtilis str QST 713 (Rhapsody)	2-10 fl oz/1000 sq ft	L	4	F6	Not Available	

Table 5.9.18 – Pesticides labeled for Rusts

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
chlorothalonil (Daconil Ultrex Turf Care)	3.7-5.03 oz/1000 sq ft	3	12	M5	311 - 423	See label for specific setback distances from water bodies. Rate depends on application timing. Labeled only for stem rust.
chlorothalonil (Pegasus DFX)	3.25-5 oz/1000 sq ft	3	12	M5	273 - 420	See label for specific setback distances from water bodies. Labeled for stem rust only. Rate range depends on application interval; see label.
chlorothalonil (Anderson's Golf Products 5% Daconil)	3.8-5.2 lbs/1000 sq ft	3	-	M5	310 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Labeled for stem rust only. Rate depends on application timing.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	4.0-5.4 fl oz/1000 sq ft	-	12	M5 + P1	229 - 309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Labeled only for stem rust on bluegrass
*NYchlorothalonil, propiconazole, fludioxonil (Instrata)	2.75-6.0 fl oz/1000 sq ft	-	12	M5 + 3 + 12	101 - 220	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Labeled for stem rust only.
*NYΔmyclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	L	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.55-1.1 oz/1000 sq ft	-	-	11 + 7	11 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	2.5	12	1	111 - 167	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	1.5-3 lbs/1000 sq ft	3.5	12	3	18 - 35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application.
tryfloxystrobin (Compass)	0.1-0.25 oz/1000 sq ft	2.5	12	11	4 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	0.6-1.5 oz/1000 sq ft	-	12	11 + 3	22 - 56	

Table 5.9.18 – Pesticides labeled for Rusts

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
Δtryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]FRAC - Resistance code assigned by the Fungicide Resistance Action Committee
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.

Table 5.9.19 – Pesticides labeled for Smuts

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NYΔmyclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	-	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year. Apply in fall after turfgrass enters dormancy.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	-	12	1	111 - 167	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	3 lbs/1000 sq ft	-	12	3	35	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application. Preventative treatment only.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
*NY - Restricted-use pesticide in New York State.

Table 5.9.20 – Pesticides labeled for Summer patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	4	4	11	7 - 15	
azoxystrobin (Heritage TL)	1-2 fl oz/1000 sq ft	4	4	11	7 - 13	
*NYchlorothalonil, propiconazole, fludioxonil (Instrata)	6-11 fl oz/1000 sq ft	-	12	M5 + 3 + 12	220 - 404	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and

Table 5.9.20 – Pesticides labeled for Summer patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
						harvested. Label lists specific rates based on application timing/interval.
*NY†fludioxonil (Medallion)	0.5 oz/1000 sq ft	L	12	12	16	
*iprodione, thiophanate-methyl (Anderson's Golf Products Fertilizer + Fung VIII)	3.04 lbs/1000 sq ft	-	-	2 + 1	97	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Use of this product at residential sites is prohibited. For suppression only.
*NYΔmyclobutanil (Eagle 20 EW)	1.2-2.4 fl oz/1000 sq ft	3	24	3	16 - 32	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	1.1 oz/1000 sq ft	-	-	11 + 7	22	For use on golf course turfgrass only. See label for specific resistance management requirements.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	2.5	12	1	111 - 167	
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	3 lbs/1000 sq ft	3	12	3	35	Harvesting or transplanting turfgrass grown on sod farms is prohibited for 17 days following application. Make first application in mid-June or 30 days prior to time this blight normally becomes evident.
tryfloxystrobin (Compass)	0.2-0.25 oz/1000 sq ft	3	12	11	8 - 10	
*NY tryfloxystrobin, triadimefon (Armada)	1.2-1.5 oz/1000 sq ft	-	12	11 + 3	45 - 56	
Δtryfloxystrobin, triadimefon (Tartan)	2 fl oz/1000 sq ft	-	12	11 + 3	39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.21 – Pesticides labeled for Take-all patch

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	3.5	4	11	7 - 15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	3.5	4	11	13	
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	1.1 oz/1000 sq ft	-	-	11 + 7	22	For use on golf course turfgrass only. See label for specific resistance management requirements.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 5.9.22 – Pesticides labeled for Typhula blight (Gray snow mold)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.4 oz/1000 sq ft	-	4	11	15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	-	4	11	13	
chlorothalonil (Daconil Ultrex Turf Care)	5.03 oz/1000 sq ft	-	12	M5	423	See label for specific setback distances from water bodies.
chlorothalonil (Pegasus DFX)	5 oz/1000 sq ft	-	12	M5	420	See label for specific setback distances from water bodies. Labeled for stem rust only.
chlorothalonil (Anderson's Golf Products 5% Daconil)	5.2 lbs/1000 sq ft	-	-	M5	424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Labeled for stem rust only.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	5.4 fl oz/1000 sq ft	-	12	M5 + P1	309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
*NY chlorothalonil, propiconazole, fludioxonil (Instrata)	5-11 fl oz/1000 sq ft	-	12	M5 + 3 + 12	183 - 404	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
*NY †fludioxonil (Medallion)	0.5 oz/1000 sq ft	-	12	12	16	

Table 5.9.22 – Pesticides labeled for Typhula blight (Gray snow mold)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NY iprodione (26GT Fungicide)	4-8 fl oz/1000 sq ft	-	24	2	64 - 128	Use of this product at residential sites is prohibited.
*NY iprodione (Anderson's Golf Products Fungicide X)	2.4-7.21 lbs/1000 sq ft	-	-	2	33 - 99	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Use of this product at residential sites is prohibited. Label lists specific rate depending on timing and disease pressure.
Polyoxin D zinc salt (Endorse)	11 lb/acre	-	4	19	7	Not for use on turf grown for commercial seed production. Aids in control.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	1.1 oz/1000 sq ft	-	-	11 + 7	22	For use on golf course turfgrass only. See label for specific resistance management requirements.
triadimefon (The Anderson's Professional Turf Products 1% Bayleton)	6 lbs/1000 sq ft	-	12	3	70	Harvesting or transplanting turfgrass grown on sodfarms is prohibited for 17 days following application. Not for use against gray snow mold on residential lawns. Apply in the fall 30 days prior to dormancy.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
*NY - Restricted-use pesticide in New York State.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.23 - Pesticides labeled for Yellow patch (*Rhizoctonia cerealis*)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
azoxystrobin (Heritage)	0.2-0.4 oz/1000 sq ft	L	4	11	7 - 15	
azoxystrobin (Heritage TL)	2 fl oz/1000 sq ft	L	4	11	13	
Bacillus licheniformis SB3086 , indole-3-butyric acid (Roots Ecoguard)	20 fl oz/1000 sq ft	-	4	NC + NC	Not Available	
chlorothalonil (Pegasus DFX)	1.82-3.25 oz/1000 sq ft	L	12	M5	153 - 273	See label for specific setback distances from water bodies.
chlorothalonil (Anderson's Golf Products 5% Daconil)	1.9-5.2 lbs/1000 sq ft	L	-	M5	155 - 424	Not for use on home lawns. Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Rate depends on application timing.
chlorothalonil, acibenzolar-s-methyl (Daconil Action)	2-5.4 fl oz/1000 sq ft	-	12	M5 + P1	114 - 309	Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested. Rate range depends on application timing and interval; see label.
*NYchlorothalonil, propiconazole, fludioxonil (Instrata)	8-11 fl oz/1000 sq ft	-	12	M5 + 3 + 12	294 - 404	Do not apply more than 20.5 oz per 1000 sq ft per year in Nassau and Suffolk Counties of New York. Sod farm turf treated prior to harvest must be mechanically cut, rolled and harvested.
*NY†fludioxonil (Medallion)	0.5 oz/1000 sq ft	2.5	12	12	16	
*NYiprodione (Anderson's Golf Products Fungicide X)	4.8-7.21 lbs/1000 sq ft	-	-	2	66 - 99	Not for use on turf grown for sale or other commercial use such as sod, commercial seed, or research. Use of this product at residential sites is prohibited. Label lists specific rate depending on timing and disease pressure.
*NYmancozeb (Fore 80 WP Rainshield)	4 oz/1000 sq ft	-	24	M3	224	Not for use on sod farms, athletic fields and residential turf.
*NYmancozeb, copper hydroxide (Junction)	2-3.6 oz/1000 sq ft	-	48	M3 + M1	104 - 188	On sod farms, harvesting of treated turf is prohibited until 5 days following application.
metconazole (Tourney)	0.37-0.44 oz/1000 sq ft	L	12	3	12 - 14	

Table 5.9.23 - Pesticides labeled for Yellow patch (*Rhizoctonia cerealis*)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
*NYΔmyclobutanil (Eagle 20 EW)	1.2 fl oz/1000 sq ft	-	24	3	16	For Nassau and Suffolk Counties in New York State, do not apply more than 3.43 fl oz of product per 1000 sq ft per year.
Polyoxin D zinc salt (Endorse)	11 lb/acre	L	4	19	7	Not for use on turf grown for commercial seed production. Aids in control.
*NY thiophanate-methyl (3336F)	4-6 fl oz/1000 sq ft	-	12	1	111 - 167	
Δtryfloxystrobin, triadimefon (Tartan)	1-2 fl oz/1000 sq ft	-	12	11 + 3	19 - 39	

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]FRAC - Resistance code assigned by the Fungicide Resistance Action Committee
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 5.9.24 – Pesticides labeled for Yellow tuft (Downy mildew)

Active Ingredient (Trade Name)	Product Rate	Efficacy[1]	REI[2] (Hours)	FRAC[3]	Field Use EIQ[4]	Comments
fostetyl-Al (Aliette WDG Brand)	4-8 oz/1000 sq ft	L	12	33	105 - 209	
fostetyl-Al (Lesco Prodigy Signature)	4-8 oz/1000 sq ft	L	12	33	105 - 209	Rate range depends on application interval; see label.
mefenoxam (Subdue Maxx)	0.5-1 fl oz/1000 sq ft	2.5	48	4	6 - 12	
mono and di-potassium salts of phosphorus acid (Riverdale Magellan)	4.1-8.2 fl oz/1000 sq ft	-	4	33	Not Available	Rate range depends on application interval; see label.
pyraclostrobin, boscalid (Honor Intrinsic Brand Fungicide)	0.5-1.1 oz/1000 sq ft	-	-	11 + 7	10 - 22	For use on golf course turfgrass only. See label for specific resistance management requirements.

[1]Efficacy - 4 = consistently good to excellent control in published experiments; 3 = good to excellent control in most experiments; 2 = fair to good control in most experiments; 1 = control is inconsistent between experiments but performs well in some instances; N = no efficacy; L = limited published data on effectiveness;
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3] FRAC codes indicate the biochemical target site of actions, according to the Fungicide Resistance Action Committee (www.frac.info). M3, M4, M5 indicate multisite inhibitor with no significant risk
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

6 Insect Management

6.1 General Guidelines

The most effective and efficient pest management programs include (1) diagnosis - correct identification of the insect(s) involved (i.e., *who* or *what* are the culprits behind the problem), (2) decision-making - a systematic process to decide if control is necessary (i.e., *whether* the situation requires a response), and (3) intervention - selecting, targeting and integrating the most appropriate control tactics (i.e., *when* and *where* to apply a control in concert with other management techniques). Navigating these stages toward improved pest management will also depend on how well we understand natural history, i.e., the associations among insects, the grasses they feed on, and the overall turfgrass habitat.

Most of the insect pests of turfgrass conduct some stage of their life underground. This poses challenges for their management because of how difficult it is to monitor, interpret and manipulate interactions that are being played out below the soil surface. Compared to above-ground foliar feeding insects, below-ground root feeding insects are harder to monitor and the products used to control them are harder to accurately deliver.

Another challenge for insect pest management is the number of exotic pests that affect turfgrass. Unintentionally introduced to the Northeast U.S., these species have arrived without the natural enemies, competitors or other factors that might have kept their populations in check across their native regions. As a result, there is great potential for outbreaks and damaging infestations. Finally, pest management in turf is also challenging because there are few non-chemical control options that offer reliable alternatives, and because the availability of chemical options is continually changing due to restrictions and market-driven alterations.

In this section on insect management we offer a general overview of the six major insect pest complexes that affect turfgrass systems in NY State such as home lawns, recreational areas, sports fields, golf courses and sod farms. We highlight aspects of turf insect biology, ecology and behavior that are important for understanding their impact as pests and for choosing and applying the most appropriate control tactics. Because this is only a general summary, we include links to additional information.

6.2 Insect Pests in NY State

There are some 17 insects that can cause serious injury to turfgrass in NY State belonging to six general complexes: (1) white grubs, (2) weevils, (3) chinch bugs, (4) caterpillars, (5) ants and (6) leatherjackets. White grubs are scarab beetle larvae that live in the soil where they feed on grass roots or otherwise disrupt the rooting zone. Weevil larvae begin as stem borers, then crown feeders, and then as adults they become foliage feeders. Chinch bugs are small, fast-moving sucking insects that live at the soil surface. Caterpillars include black cutworms, sod webworms, and fall armyworms that are primarily active at the soil surface where they feed on above-ground foliage. Ants are relevant

Table 6.2.1. Major insect pests of NY State turfgrass.

Group	Common name	Scientific name	Most damaging life stage[1]		Origin
			Name	Habitat	
White grubs	Asiatic garden beetle	*Maladera castanea*	Grub	Root zone	Exotic
	Black turfgrass ataenius	*Ataenius spretulus*	Grub	Root zone	Native
	European chafer	*Rhizotrogus majale*	Grub	Root zone	Exotic
	Green June beetle	*Cotinis nitida*	Grub	Root zone	Native
	Japanese beetle	*Popillia japonica*	Grub	Root zone	Exotic
	May and June beetles	*Phyllophaga anxia*, others	Grub	Root zone	Native
	Northern masked chafer	*Cyclocephala borealis*	Grub	Root zone	Native
	Oriental beetle	*Anomala orientalis*	Grub	Root zone	Exotic
Weevils	Annual bluegrass weevil	*Listronotus maculicollis*	Grub	Soil surface	Native
	Bluegrass billbug	*Sphenophorus parvulus*	Grub	Soil surface	Native
Chinch bugs	Hairy chinch bug	*Blissus leucopterus*	Nymph, Adult	Soil surface	Native
Caterpillars	Black cutworm	*Agrotis ipsilon*	Caterpillar	Soil surface	Native
	Fall armyworm	*Spodoptera frugiperda*	Caterpillar	Foliar	Native
	Sod webworms	Various	Caterpillar	Soil surface	Native
Leatherjackets	European crane flies	*Tipula oleracea*, *Tipula paludosa*	Maggot	Root zone, Soil surface	Exotic
Ants	Mound-building ants	*Lasius neoniger*, others	Adult	Soil surface	Native

[1]Grub, caterpillar, nymph and maggot are terms for the immature life stage of different insect groups

when their nests disrupt the surface of the ground. Leatherjackets are the soil-dwelling larvae of crane flies that injure grass both above- and below-ground. The injury caused by these insects can be difficult to differentiate from each other and from certain plant diseases. Nevertheless, control decisions must be based on a correct identification of the insect pest, which means recognizing the injury and knowing how to identify the insect complex and insect species involved. Diagnosis is fundamental because the timing and type of control tactics will depend on the particular species involved, and moreover because chemical control products have labels specific to particular groups of insects. A misdiagnosis means that applicators will not be in full compliance.

6.2.1 White Grubs

Description. White grubs are the larval, or immature, stages of scarab beetles, constituting the most diverse, widespread and damaging group of turf pests in the Northeast U.S. In NY these include four native species (black turfgrass ataenius, green June beetle, May or June beetles, northern masked chafer) and four introduced species (Asiatic garden beetle, European chafer, Japanese beetle, Oriental beetle). While this pest complex occurs across the entire state, the most prevalent species at any one site will vary considerably. Up to four species might occupy the same patch of turf, but the composition and relative abundance of those species will depend on local conditions due to diverging habitat preferences. For instance, Japanese beetles may be more prevalent in irrigated turf such as golf course fairways, while European chafer might be more prevalent in non-irrigated rough. The green June beetle is an exception to widespread occurrence as it is not known outside of southeastern NY.

Natural history. Larvae have well-developed mandibles for chewing on grass roots. The younger larvae may ingest a high proportion of organic material in addition to feeding on fibrous roots. All cool season grasses are susceptible, as well as some species of forage, field and nursery crops. While the adults of some species feed and are damaging to ornamental plants in their own right (e.g., Japanese beetle, Asiatic garden beetle), the adults of other species may not feed at all (e.g., European chafer). No adults feed directly on turfgrass.

Larvae are truly subterranean, moving horizontally through the soil to track food resources and moving vertically in response to drought and temperature. Adults are generally strong fliers, mobilizing to locate mates and egg-laying sites. Because of this, having a lot of adults does not necessarily translate to a lot of grubs. Local control of adult populations will not solve grub problems, nor will local control of grub populations solve adult problems (e.g., Japanese beetle feeding on ornamentals).

Adults of most species rely on female-produced pheromones to attract males for mating. One exception is the European chafer. Males and females of this species aggregate at dusk around prominent trees, vegetation or structures to find mates as they apparently do not use long-distance pheromones. Adult females lay eggs within the top 8 inches of soil, either singly or in small groups. After egg hatch, development proceeds through three larval instars, then prepupa, pupa and adult.

In NY, most species complete one generation a year and overwinter as third instars. As winter approaches, larvae descend to stay below the frost line, and ascend in spring as the frost line recedes. They descend once more for pupation. It is the prepupa that fashions the earthen cell in which the pupa resides until the adult emerges and crawls to the surface. Corresponding to its small size, the black turfgrass ataenius can complete two generations a year and overwinters as an adult. The inverse is true for the large May or June beetle grubs, which may require 2-3 years to complete a single generation.

Most damage is attributed to the large third instar due to extensive pruning (chewing) of the roots at the soil-thatch interface. This kind of injury disrupts water and nutrient flow and, if accompanied by drought stress, the grass will quickly die. High populations can kill extensive areas of turf. Unlike other species, larvae of the green June beetle cause damage by their active tunneling through the root zone, not by direct feeding on roots. Most of their nutrition is obtained by ingesting soil organic matter rather than living roots.

Diagnosis. Larvae are "C"-shaped, with six legs, and well-developed mandibles attached to a defined head capsule. The eight species that occur in NY can be differentiated based on two characters of the abdomen: the raster pattern and the anal slit. The raster pattern is the specific arrangement of hairs, spines and bare patches on the ventral surface of last abdominal segment. The anal slit can be straight or "Y"-shaped. With practice and the help of a hand lens, these features can be distinguished in the field at least for the larger third instars. These two characters are definitive for identifying turf-infesting grub species in NY. More information can be found at https://blogs.cornell.edu/wickings/files/2015/01/GrubKey_vWeb-2aiek0t.pdf.

When turf is heavily damaged it will feel spongy, not firm, underfoot. It will peel back from the soil like a carpet because the root system has been disrupted or devoured. Above ground, there will be thinning, increased susceptibility to drought and ultimately increased susceptibility to weed invasion. If grub populations do not cause visible damage, then their predators might. The grubbing activities of vertebrates like raccoons, skunks and moles can be highly problematic. It is common that indirect grubbing damage is more troublesome than direct grub damage.

If your goal is to monitor the activity of adults in anticipation of a preventive application around the time of egg hatch, Japanese beetles can be monitored with vane traps (baited with a pheromone and floral lure), European chafer by observing mating swarms, and Asiatic garden beetle by nocturnal sweeping of the grass with an insect net or by its attraction to lights or light traps. More often, however, it is the damaging larval stage that has to be monitored in support of decision-making. To detect larvae or assess their abundance, you have to dig. Unlike certain other turf insects such as caterpillars, disclosing solutions will not force white grubs to the surface. Use a golf course cup cutter, bulb planter, or shovel to examine soil cores for grubs in the root zone. Depending on the size of the species, eggs and first instars are relatively difficult to find, while second and third instars are relatively easy to pick out of the soil.

Decision-making. The potential for future damage can be predicted by sampling for grubs that have not yet caused significant injury. The best time to sample is early August in southeastern NY and mid-August upstate. Egg hatch and grub development, however, may be delayed by cool or dry weather and may also vary from species to species. A sampling scheme should be based on identified problem areas, susceptible areas, and areas that otherwise require better protection (e.g., front lawns, fairways). High priority and high risk areas should be sampled more completely to reduce the chances of overlooking a damaging infestation.

Table 6.2.2. White grub treatment thresholds.

	Number of grubs per	
Species	**sq. ft.**	**core[1]**
Asiatic garden beetle	18-20	2
Black turfgrass ataenius	30-50	3-5
European chafer	5-8	Any
Green June beetle	5	Any
Japanese beetle	8-10	Any
Oriental beetle	8	Any
Northern masked chafer	8-12	Any
May and June beetle	3-4	Any

[1]4.25-inch diameter soil core of the standard golf course cup cutter

Thresholds have been established as general guidelines for treatment (Table 6.2.2). If several areas are at or above the threshold, intervention may be warranted. Remember, turfgrass that receives sufficient water and has a healthy root system will tolerate higher numbers of grubs than the suggested thresholds. Extensive research in upstate NY shows that insecticide treatments are needed only 20% of the time on home lawns and golf course fairways. In other words, if the decision-making process is bypassed by the consistent use of an early season preventive insecticide, the application may have been unnecessary four times out of five.

Intervention – Cultural control. There is no specific host plant resistance among turf grasses to white grubs. It is therefore not possible to select a grass that eliminates grub problems. Kentucky bluegrass and creeping bentgrass, however, have a spreading growth habit that is beneficial for filling in bare patches caused by grubs. Endophyte-enhanced grasses (e.g., some perennial ryegrass and tall fescue) may be more tolerant of drought stress and recover more quickly from grub damage even though they do not confer resistance per se. Soil moisture and fertility affect the expression of damage by white grubs. Actively growing turf with a good root system may tolerate populations up to 50% higher than treatment thresholds without showing signs of injury. The recovery of grub-damaged turf can be hastened with autumn fertilization. A high-nitrogen application in the spring, however, is detrimental because it weakens the grass by encouraging shoot development without a good root system. Counteract root loss with regular watering and counteract thinning of the stand with overseeding.

Intervention – Chemical control. There are two basic insecticidal approaches to managing white grubs. One is to make a preventive summer application of a slow-acting and long-lasting material, like chlorantraniliprole or imidacloprid, that will prevent subsequent infestations. The second is to wait until mid-August, after egg hatch, and sample for the presence, abundance and distribution of grubs. Areas with populations above threshold levels can be spot treated with a curative insecticide. Data support that imidacloprid can still be effective if used in August. Trichlorfon is a fast-acting, short-lived insecticide that is usually effective in both September and October. However, practitioners should consider the relatively high EIQ of trichlorfon when selecting a treatment strategy. Entomopathogenic nematodes are an alternative curative treatment that can be considered, and are discussed later in this chapter.

The use of a preventive insecticide may be warranted in areas that consistently suffer damaging grub populations, or in risk-adverse situations with high value or high priority turf. The advantages of this approach are (1) the available chemistries have a relatively low EIQ, mammalian toxicity and low rate of active ingredient, (2) a fairly forgiving window of application, (3) if the application fails, other alternatives are available as a late season backup, and (4) no scouting is required. One drawback of this approach is that applications are made too early in the season to scout for grubs. Contrary to best IPM practices, this means that population levels cannot be assessed and compared to damage thresholds for decision-making. A second drawback is that insecticides with longer residuals will also have longer windows of exposure to non-target fauna, which have a role in the natural regulation of pest populations and other beneficial processes including thatch decomposition.

In contrast, use of a curative insecticide can be based on known populations. The specific advantages are that (1) scouting can be used to assess population levels, locations, and species present, (2) intervention decisions can be made based on thresholds, (3) spot treatments can be made over smaller areas, and (4) the fast-acting insecticide, trichlorfon, degrades rapidly. Aside from the labor and cost of scouting, a main drawback of this approach is that there is usually no second chance if the application fails. Another drawback is that trichlorfon has relatively high EIQ, mammalian toxicity and rate of active ingredient.

Curative spring treatments for grub control are not recommended. Although grubs are feeding vigorously at that time of year between overwintering and pupation, the feeding time is relatively short, the grubs are typically as large as they are going to get and are very tolerant of insecticides. In addition, most damage has already occurred and the spring flush in grass growth can usually compensate for grub damage. Regardless of approach, the goal of treatment is never to eradicate completely, but to reduce the population below damage thresholds.

Imidacloprid is a broad-spectrum, long-residual insecticide. This compound is widely relied upon for white grub control in commercial turfgrass. It mostly functions as a systemic so it should be well watered in to reach the roots where it will be taken up by the plant after an activation period. The optimal time to use imidacloprid is at the time of egg laying and egg hatch. Nevertheless, its long-residual gives it a relatively forgiving window of application, from early June to mid-August. While largely used preventively, before scouting is possible, recent research shows that it may be effective against Japanese beetle as late as second instar. Because this developmental stage can be scouted, it opens opportunities to use imidacloprid as a curative. This approach might be suitable if scouting reveals a previously undetected and widespread infestation that is predominately second instar Japanese beetle. In this case, imidacloprid would be a viable option to pursue before a widespread application of a curative alternative. But unless a manager has a good understanding of the timing and potential asynchrony of population development (e.g., Japanese beetle can lay eggs over a period of more than two months), caution should prevail.

All commercial applications of imidacloprid products are restricted-use statewide in NY. In addition, the sale, use, and distribution of consumer products are not allowed in Nassau, Suffolk, Kings or Queens Counties.

Chlorantraniliprole is a broad-spectrum and long-residual insecticide. It can be applied as soon as early April for preventive control, and in August and possibly early September for early curative control. Later season applications may require the high label rate for effective control of second instar larvae. All species of white grubs are susceptible to this insecticide. There is also proven efficacy against many of the other turf-infesting insects in NY. Given its long-residual activity, season long control is probable against white grubs and possible against other insect pests. Subsequent infestations of caterpillars, billbugs, annual bluegrass weevils and European crane flies might be suppressed in chlorantraniliprole-treated turf. When feasible, use scouting to determine whether insecticide applications against those other pest species might be withheld.

Trichlorfon is a fast-acting, short-residual insecticide recommended for curative spot treatments. Trichlorfon is highly soluble and penetrates the thatch layer better than most products. It has an extremely short period of residual activity (7-10 days) and a reduced half-life in alkaline soils. This product is recommended as a late-season curative and should be applied after the grubs have been located, up to as late as mid-September. It should be noted that trichlorfon has a relatively high EIQ, and that carbaryl is the only alternative to trichlorfon for late season and fast-acting control.

Intervention - Biological control. Three biological control agents are commercially available for management of white grubs in turf: entomopathogenic nematodes, entomopathogenic fungi, and the bacteria that cause milky spore disease. Nevertheless, all alternatives have relatively poor or inconsistent results in the field. Therefore, while turfgrass managers might experiment with these products, they should not rely on them for grub management in high-priority areas. They may also be better than nothing in areas where cultural management is insufficient and chemical treatments are either not desired or not allowed.

Entomopathogenic nematodes. Entomopathogenic nematodes can be effective parasites of white grubs. Although they are sometimes as effective as chemical insecticides in laboratory trials, field results are inconsistent and failures are common. Reasons for poor field results include insufficient water at time of application, improper selection of nematode species, improper storage and handling of the nematodes, and unsuitable environmental conditions such as high soil compaction.

Nematodes work in concert with a mutualistic bacterium that they carry in their guts. The infective juvenile stage of nematodes lives freely in the soil; when the juveniles encounter a suitable insect host, they enter through natural openings (e.g., mouth, spiracle or anus) or are sometimes able to penetrate the insect's cuticle. Inside the host, the nematodes travel to the gut and deliver the lethal bacteria that they vectored inside. The bacteria multiply rapidly, releasing a toxin that kills the host in 1-2 days. The nematodes also multiply inside the host until resources are depleted. At that point, a new generation of infective juveniles exits the cadaver to search for another host in the soil.

Among the available commercial isolates of nematodes, *Heterorhabditis bacteriophora* is the species recommended for the management of white grubs, however, Steinernema feltiae may also prove effective in porous, sandy sites. *S. glaseri* are also effective but may not be available commercially. They should be applied while grubs are still young and most susceptible and before they have caused significant damage. Follow sampling suggestions above, and apply nematodes in areas where high populations have been confirmed. Many types of pesticide sprayers can be used. Use low pressure (< 300 psi), and remove any screens finer than 50 mesh. A hose-end sprayer or watering can is ideal for small-scale applications. Apply a minimum rate of 1 billion nematodes per acre, regardless of the manufacturer's directions.

Because nematodes are harmed by ultraviolet light, they should be applied at dusk or on a cloudy, rainy day. The nematodes use the thin film of water surrounding soil particles for movement. Irrigation (1/4 inch) after a nematode application is thereby suggested to optimize soil conditions and to help move nematodes through the thatch. A light irrigation before the application will also reduce the chances of nematodes sticking to grass blades on the surface. Users are advised to check viability by examining nematodes for movement with a hand lens before application and again in a sample collected from the sprayer output.

Fungal entomopathogens. *Beauveria bassiana* (the "white muscardine" fungus) is a common soil-borne fungus that has been selected for its virulence to certain insect pests. When spores (conidia) attach to the insect cuticle, they germinate, penetrate with the growing hyphae, and proliferate within the insect's body. Moist conditions favor germination, followed by infection of the insect host 1-2 days later, and ultimately death. The white appearance of the cadaver's surface is due to the conidia produced by the mature reproductive structures of the fungus as they reemerge from the host. These infected cadavers serve as inocula for secondary spread of the pathogen in the environment.

The commercial product of *Beauveria bassiana* is produced through fermentation. Conidia are harvested and formulated into a sprayable liquid. Speed and efficacy of the product will depend on the number of spores contacting the insect, the age and susceptibility of the grub and the environmental conditions. Therefore, younger white grubs should be targeted because they are more susceptible than third instars. Additionally, after application, the area should be kept wet to promote germination and subsequent infection.

Milky spore disease. Milky spore disease powder is produced by grinding up living, diseased Japanese beetle grubs infected with the bacteria *Paenibacillus popilliae*. Commercial preparations of milky spore powder are widely used for the biological control of Japanese beetle. Nevertheless, the efficacy of current formulations has not been scientifically substantiated in the field, leading to questions about the usefulness of this biological control agent for white grub management. Users must also be aware that the bacteria in formulated products have been selected for infectivity to Japanese beetle grubs and are of no value against other common grub species infesting turfgrass in NY. This host specificity is highlighted on the product label. While Asiatic garden beetle, European chafer and Oriental beetle harbor the bacteria in natural populations, the commercial variety is specific to Japanese beetle.

While scouting, you may find milky grubs that are naturally infected with local strains of bacteria. The widespread occurrence of this pathogen under natural conditions means it does have prospects for biological control of white grubs. But, this will depend on further research and development to transfer laboratory virulence into field efficacy, as well as selecting more virulent bacteria that act against more species of scarabs under broad climate conditions. Practitioners seeking alternatives to chemical insecticides can try this product, but should not rely upon it.

More information online:

White grub control:

- www.nysipm.cornell.edu/publications/grubs
- http://www.omafra.gov.on.ca/english/crops/facts/08-023w.htm

Japanese beetles:

- www.omafra.gov.on.ca/english/crops/facts/92-105.htm
- https://ohioline.osu.edu/factsheet/ENT-46

Asiatic garden beetle:

- https://ag.umass.edu/landscape/fact-sheets/asiatic-garden-beetle

Masked chafers:

- https://ohioline.osu.edu/factsheet/ENT-51

Biological control:

- https://ag.umass.edu/turf/professional-turf-ipm-guide/insect-management/biological-management-of-turf-insects

6.2.2 Weevils

Description. The bluegrass billbug (BGB, *Sphenophorus parvulus*) and the annual bluegrass weevil (ABW, *Listronotus maculicollis*) are native weevil species. BGB is most injurious in high-cut, lower maintenance turf such as home lawns, athletic fields and golf course roughs. It impacts turf throughout the northern U.S. ABW is most injurious in low-cut, high maintenance turf such as golf course greens, tees and fairways. Until approximately 20 years ago, outbreaks were largely limited to southeastern NY, but now the area of impact has expanded throughout much of the state, north to New England and Quebec, west to Ohio, and south to Virginia.

Natural history. For BGB and ABW, females chew holes into the grass stem and insert eggs. Young larvae live as stem borers, chewing and consuming tissue within the relative protection of the stem and filling it up with frass (insect excrement) that looks like sawdust. When they outgrow the stem, older larvae will drop down to the soil surface where they forage out to chew on surface roots and crowns. Adults feed on grass blades but cause little damage. Both species develop through five larval instars, prepupa, pupa and adult. Pupation takes place in the top layer of the soil. BGB completes only one generation a year, while ABW completes two to three, and as many as four in southeastern NY.

Adults of both species are capable walkers, and largely disperse on foot even though they are capable of flight. In autumn, they mobilize to overwintering sites away from developmental areas. BGB adults, for instance, may settle into where sidewalks meet the lawn. ABW will seek out the relative protection of tree litter and tall grass, and may be most prevalent along defined tree lines or hedgerows bordering fairways.

Diagnosis. Adults have long snouts that are the hallmark of the weevils. BGB adults measure about 1/4 inch long, or about twice the size of ABW (about 3/16 inch long). In addition to overall size, BGB adults can be differentiated from ABW because their antennae arise from the base of the snout, rather than the tip. Newly emerged adults, known as "callows" or "tenerals," are chestnut to brown in color, making the young adults distinguishable from mature adults that are dark grey to black.

The bodies of BGB and ABW larvae are straight to slightly curved and creamy white in color with a well-defined brown head capsule. Unlike most beetles, weevil larvae are legless, meaning that they are easily distinguished from white grubs, which have six legs and a "C"-shape.

Injury caused by the stem boring and tunneling activities of younger larvae can be revealed through the "tug-test." Brittle or weakened stems are easily pulled up by hand. Unlike white-grub injury, the soil and root zone remain firm and not spongy. BGB-damaged turf appears wilted, as if drought stressed, but it will not respond to watering. Damage is ultimately expressed as growing brown patches, especially near drought-prone edges such as pavement where grass may be more susceptible to heat or water stress. To distinguish BGB from drought stress, look for the frass as small pockets of sawdust-like material in the thatch or inside grass stems. BGB is most prevalent and damaging in Kentucky bluegrass. Damage is most apparent from late June through August.

ABW injury is usually expressed as growing areas of yellow and brown spots first noticed around the collar and perimeter of greens, tees and fairways. Early ABW damage has anthracnose-like symptoms and is frequently confused with this pathogen. Damage will be most prevalent in annual bluegrass, the favored host. It is unknown whether ABW can actually complete its life cycle on other hosts, even though it is capable of feeding on creeping bentgrass and perennial ryegrass. High populations of ABW will cause substantial areas of dead turf in highly visible and prominent areas of golf course playing surfaces.

BGB – Decision-making. BGB adults are most active in spring, from mid-May to June. It is common to see them strolling across pavement or sidewalks in the mid to late afternoon. One way to monitor them at this time of year is with pitfall traps. Make a hole with a standard golf course cup cutter, insert a plastic cup that fills the hole and is submerged to the rim, and add an inch of water with some dish detergent. If 7-10 billbugs fall in over a 2-3 week period, injury can be expected in the surrounding turf. Another approach in spring is to observe adults walking on paved surfaces adjacent to turf. Injury can be expected if >2 are observed per minute. For the larvae, tolerance thresholds are 8-12 per sq. ft.

BGB – Intervention. If potentially damaging populations are detected, chemical control applications should be made between mid-May and late June. This window targets adults once they have emerged from overwintering sites and before they lay eggs. It is best to mow before the application and irrigate lightly afterwards. This intervention should prevent severe damage by larvae in July and August.

In areas with persistent problems, host plant selection should be considered. One of the most susceptible cool season grasses is Kentucky bluegrass. This species should be avoided in favor of more tolerant alternatives. Endophytic cultivars of tall fescue and perennial ryegrass are also good options because they reduce BGB survival.

ABW – Decision-making. ABW can be challenging to monitor due to its small size. In the spring, mower baskets can be monitored for adults because they are picked up along with clippings. This can be a useful way to stay abreast of when adults are appearing in spring, and, with more careful monitoring, on which areas of the course they are most prevalent. Some areas of the course may always harbor ABW so it is a good idea to monitor consistently those historically affected areas from year to year. Adult ABW reinvade short-mown turf soon after snow melt and soil thaw, from late March to April.

A more site-specific approach to monitor adults is to pour a soapy disclosing solution on the turf. The standard method is to mix 1 fluid ounce lemon-scented dish detergent in 2 gallons water and apply it over 2-3 square feet of turf. The soap acts as an irritant, forcing adults to emerge from the thatch and ascend to the surface where they can be counted. Shallow soil core sampling or simply digging around at the soil surface/thatch interface will reveal older larvae and pupae. Older larvae look like grains of rice with brown heads; pupae resemble adults but are creamy white until their color darkens before adult emergence. If more detailed information is desired, larvae of all sizes (even stem boring stages) will float to the surface when an infested core is submerged and agitated in a saturated salt solution. This is a good way to confirm that your adult controls were

adequate; if too many larvae are found, the application may have been poorly timed to suppress adults and another application against adults of the developing population may be necessary.
Damage thresholds are 30-80 larvae/sq. ft. for the spring generation. Given summer heat stress, thresholds drop to 10-40 larvae/sq. ft. for the summer generation. Nevertheless, field experience indicates that action may have to be taken at thresholds as low as 5-10 larvae/sq. ft. in order to avoid injury and minimize the threat of the subsequent generation.

ABW – Intervention. Best control is achieved by targeting early spring adult populations that represent overwintered insects returning to the short mowed turf. A preventive insecticide application is then made to suppress adult populations before eggs are laid. The timing of spring applications can be based on a plant phenological indicator. The most widely used is the period that occurs between Forsythia full bloom and flowering dogwood full bract. It is better to make the spring application a little late than a little early, so aim for the time when Forsythia is in full bloom and has already acquired many new leaves (i.e., “half gold/half green”).

Choose a relatively insoluble insecticide that stays in the thatch where adults are active. Chlorpyrifos and pyrethroids are the best options. Water in the application lightly, enough to move the material off the leaves. Widespread fairway applications are usually not necessary. It should be sufficient to limit applications to periphery sprays along historically susceptible greens, collars, tees and fairway perimeters. If this control fails, second generation adults can be targeted again sometime around July 4.

In southeastern NY, insect resistance to pyrethroid insecticides is well documented. It is unclear how widespread this resistance may be across the rest of the state. If you have made multiple seasonal applications of pyrethroid insecticides to target adults over several years, then your local populations may no longer be suppressed by these insecticides. Non-pyrethroid alternatives include chlorantraniliprole, cyantraniliprole, indoxacarb, spinosad and trichlorfon, which largely target larvae. Unlike the other larvicides, chlorantraniliprole should be applied early when overwintered adults reappear so it is fully activated once the larvae emerge. Given the difficulties in timing applications against ABW, all intervention approaches should be backed up by a sampling plan that will verify product efficacy. No insecticidal products have activity against the pupae.

With respect to cultural control, minimizing stress (e.g., due to water deficit or traffic) on annual bluegrass might mitigate the effects of ABW. Other than that, reducing the amount of annual bluegrass is the only other option as this may leave turf less favorable for the development of outbreak populations. Overwintering adults are sometimes very abundant in white pine litter, leading some golf courses to remove pine litter or even remove stands of white pine trees. Tree removal is not recommended, however, because these sites are not actually preferred locations for overwintering. Weevils will overwinter elsewhere. We may ultimately be able to define control practices based on managing adults in their overwintering habitats or by intercepting them as they return to developmental sites, but these opportunities have not yet been advanced.

More information online:

Annual bluegrass weevil:

- www.nysipm.cornell.edu/factsheets/turfgrass/default.asp

Billbug:

- ento.psu.edu/extension/factsheets/billbugs-lawns
- https://ohioline.osu.edu/factsheet/HYG-2502-12

6.2.3 Caterpillars

Description. Three groups of caterpillars damage turf in NY: cutworms, sod webworms and armyworms. Cutworms and armyworms largely refer to diverging habits of these moth larvae. Cutworms are solitary and tend to chew through and sever the grass stem at ground level, and then move on to the next plant. In contrast, armyworms are gregarious feeders, and tend to move across the turf eating all edible material in their paths. While there are a few species that can be injurious in turfgrass of NY, the main species of concern are the black cutworm (BCW, *Agrotis ipsilon*) and the fall armyworm (FAW, *Spodoptera frugiperda*). FAW and BCW do not usually overwinter in NY because they are too cold intolerant. Migratory adults reinvade the state every spring from populations that overwinter in the southern U.S. Sod webworms on the other hand are a complex of species that do overwinter in NY.

It should also be noted that the “true” or “common” armyworm (*Mythimna unipuncta)* is a sporadic invader in New York. Outbreaks typically occur in some area of the state every 3-8 years, and result from moths blown in on weather fronts from the southern or midwestern US. The infestation of 2012 was the most severe and widespread on record in NY. Like FAW, true armyworms are not known to overwinter here.

Sod webworms. Sod webworms are only sporadic pests and the cases are actually few where the larvae become problematic, despite the large numbers of adults that may be seen. Adults have snout-like projections on their face (thereby their common name “snout moths”) and have their wings folded close to the body when at rest. They are buff-colored and 0.5-0.75 inches long. They hide during the day. When disturbed by mowing, however, or at dusk, they fly in a zigzag pattern and are easy to spot.

Larvae construct silk-lined burrows through the thatch layer and into soil, incorporating debris such as soil, sand and grass clippings in the tunnel walls. They emerge at night to forage outside the burrows. Larvae grow up to 1-inch-long, are brown to green in coloration with a series of darker spots. Foraging birds may indicate infestations. Habitat preferences are for sunny areas, and they can affect low to high maintenance turf (e.g., home lawns and golf course turf). Sob webworms overwinter as larvae.

Damage starts as small patches of yellowing or browning grass, or grass clipped off at ground level where grass is turning brown. Look for small piles of green frass. On low-mown turf, sod webworm damage can resemble disease, and will cause small depressed marks of brown grass that grow in size.

The highly visible adults often concern home owners, but their presence does not indicate a pest problem. Therefore, the lawn has to be monitored for the larvae. More often than not, damage attributed to sod webworm on residential lawns is actually just drought stress—another reason it is important to scout for larvae. Conduct scouting for larvae two weeks after adult flights, when caterpillars from the new generation will be present. Scout near brown patches by spreading the grass and looking into the thatch to find the frass. Another way is to flush them to the surface using a soapy disclosing solution (see 6.2.2).

If the number of larvae or amount of damage warrants control, use less soluble insecticides that will stay in the thatch, such as pyrethroids. Because larvae are most active at night, a product should be applied as late in the day as possible. It should be watered in lightly, just enough to wash it off the leaves and into the thatch. Spinosad and Bt are biopesticide alternatives to conventional chemical insecticides for sod webworm management.

Black cutworm – Natural history. While BCW is common in low maintenance turf, it is particularly damaging in golf course greens and tees. Each spring adult moths reinvade NY from the southern U.S. along with spring storm fronts. This species is apparently incapable of overwintering in areas where the soil freezes. BCW can complete 2-3 generations a year in NY. Adults feed on flowers at night and then locate sites in the turf where they attach eggs to the tips of grass blades. Small larvae move across and feed on the surface. Older larvae, however, fashion a protective burrow in the turf from which they foray to feed. These burrows lead into the soil and are about the size of a pencil hole.

Black cutworm – Diagnosis and decision-making. BCW adults are dark grey and mottled with black and brown. Larvae bear a pale stripe down the back, a greasy or oily appearance, and have a surface integument that is rough or pebbly. Mature larvae will get to be 1-2 inches long. Nocturnal feeding will scalp grass around the burrow's entrance, leaving irregular depressions that resemble ball-marks or even dollar-spot. Low-mown bentgrass is particularly susceptible to damage. Like sod webworms, foraging birds may help to indicate the presence of larvae. The first appearance of adults in NY can be monitored in spring using either black light or pheromone traps set out early in the season. Both traps have limitations. Pheromone traps are relatively inexpensive and simple to maintain, but catch only male moths. While black light traps capture both male and female moths (along with a wide range of other insects), they are expensive and labor intensive. Because storm-driven moths are deposited randomly, there is no guarantee that lack of captures means that no females are present, nor is there any way to equate capture numbers to infestation levels; thus the usefulness of these traps is limited. A positive capture means only that chances are good that females are present and that larvae may appear within a week.

Monitoring for larvae should begin one to two weeks after the initial moth trap catches. Use a soap drench (see section 6.2.2) over 3-4 areas of the green's surface to detect their presence. On golf course putting greens, damage may not be noticed until the larvae are quite large or have reached the fourth instar. At this point, the disclosing solution can confirm the diagnosis of cutworm damage. Pest management strategies, however, should target detection and treatment of cutworms before this stage. Thresholds will vary widely from greens and tees to fairways. While the visible damage of only 3-4 large larvae on greens might require a control, turf maintained at a higher cutting height can tolerate much higher populations before thinning is apparent.

Black cutworm – Intervention. Cultural control takes advantage of the fact that BCW lays the majority of eggs on the terminal portion of leaf blades, regardless of mowing height. Most eggs can therefore be removed if the clippings are collected. These should be discarded at least 100 feet away from susceptible turf areas to prevent return migration of the newly hatched caterpillars. Larvae shun feeding on Kentucky bluegrass. A 30-foot buffer of this grass around a golf course putting green significantly reduces the incidence of cutworms since they are less likely to cross this barrier to settle on the greens. Another alternative is to mow greens early in the morning, between 2 and 4 a.m., when cutworms are actively feeding on the surface. Target these mowings for three consecutive nights during the development of early instars for each cutworm generation. Planting endophytically-enhanced varieties of perennial ryegrass and tall fescue in appropriate areas is also an effective way to avoid or reduce damage.

Spinosad is a biologically-derived, low EIQ product that is effective against cutworms. It works best against young caterpillars, and is relatively fast acting. Otherwise, a range of chemistries work well for the curative control of BCW. Early-season detection and treatment is desirable because younger (smaller) cutworms are more susceptible than older (larger) cutworms. Higher rates might be required for the control of large larvae and for control in high-mown turf. Regardless, after application, irrigation and mowing should be withheld for 12-24 hours so larvae can contact the treated foliage.

Besides spinosad, Bt-based biopesticides are an alternative to conventional chemical insecticides. Bt is a non-living form of the bacterium *Bacillus thuringiensis* that is sold and labeled for management of caterpillars, including black cutworm, sod webworm and armyworm. This microbial toxin will also be most effective when targeting the more susceptible smaller larvae. As with chemical treatments, mowing and irrigation should be withheld 12-24 hours.

In the area of biological control, entomopathogenic nematodes have a good chance of success in managing BCW. Use the nematode species *Steinernema carpocapsae*. As with the biopesticides, apply when caterpillars are small, and follow the recommendations described in the section under white grubs. Finally, keep in mind that a diverse array of naturally occurring enemies, such as parasitic wasps and flies, ground beetles and rove beetles help to suppress cutworm populations.

More information online:

Black cutworm:

- www.ento.psu.edu/extension/factsheets/black_cutworm.htm
- https://ohioline.osu.edu/factsheet/ENT-35
- entomology.unl.edu/turfent/documnts/cutworms.shtml

Fall armyworm:

- www.ces.ncsu.edu/depts/ent/notes/O&T/lawn/note128/note128.html

Sod webworm:

- www.ento.psu.edu/extension/factsheets/sodWebwormLawns.html
- http://entomology.unl.edu/turfent/documnts/swebwrms.shtml

6.2.4 Chinch Bugs

Description. The hairy chinch bug (HCB, *Blissus leucopterus hirtus*) occurs throughout NY, west to Minnesota, south to Virginia and north to Ontario and southeast Canada. Home lawns are the most susceptible turf habitats. The insect is most prevalent in areas with thick thatch, well-drained sandy soils and full sunlight. In addition, HCB is recently and increasingly recognized as an occasional pest on golf courses where it has traditionally been of little concern to superintendents.

Natural history. HCB has piercing-sucking mouthparts that permit the nymphs and adults to extract sap from the crowns and stems. This causes injury that produces drought-like symptoms. Most of the cool season grasses are susceptible to feeding. Both life stages are active and agile in the thatch and on the soil surface. HCB tends to form aggregations and this leads to patches of localized damage. Although adults are capable of flight, they largely disperse by walking. Adults will move to overwinter in protected sites with thatch or tall grass, in debris and around structures. When they re-emerge in the spring, egg laying is preceded by a nearly 2-week preoviposition period. Up to 170 eggs per female are laid in leaf sheaths and on the ground near the base of host plants. Nymphs require 4-6 weeks to develop through five instars. One generation per year is most common in upstate NY and two generations is probably most common downstate.

Diagnosis. HCB are small and relatively fast-moving insects. Adults are 3/16 inches long, with shiny white wings. Nymph coloration varies from red to orange to brown. When captured by hand, odoriferous defensive glands on the abdomen will emit a powerful and pungent fruity smell.

The habitats most susceptible to HCB damage are home lawns with full sun and sandy soil where grass is more susceptible to drought stress. Abundance of the insect and severity of its injury are also favored by thick thatch. July and August are the months when the insect is most active and when most damage is expressed. HCB feeding causes symptoms that resemble water stress and can be misdiagnosed as such. Unlike drought, however, lawns that are heavily damaged by HCB will not recover once wet conditions are restored. Affected grass will turn yellow and then reddish-brown. Injury may be more prominent on the edges of paved areas.

Searching the soil surface should reveal the nymphs and adults. The tiniest nymphs are bright orange/red, and the adults are quick, which makes them relatively easy to spot despite their small size. HCB can also be detected and monitored with a flotation cylinder. Choose a spot on the fringe of a patch of damaged grass. Pound an open-ended coffee can about2 inches into the soil, fill it with water, and look for the adults as they float to the surface. Add more water as required if it filters into the soil. A 5-10-minute observation should be sufficient. Alternatively, remove a soil/turf core with a cup cutter or shovel, and submerge the sample in a bucket or pan filled with water.

Decision-making. If an infestation of HCB is detected, make several observations with the flotation cylinder at the margin of the affected areas. More than 20 HCB per cylinder means that action should be taken to avoid loss of turf. Population estimates can also be made with direct visual counts. More than 10 individuals found in a 60-second search of 1 sq. ft. has been used as an action threshold, as has 20-30 per sq. ft. in a detailed search. Make these abundance estimates at several sites around the affected area, and over time to judge whether levels are increasing or decreasing.

Intervention. Studies have shown a great deal of variation in HCB susceptibility across different cool season grass species and varieties. Therefore, host plant selection is a form of cultural control that can be used. Heavily or consistently damaged lawns should be renovated with a more tolerant grass variety. Endophytic cultivars of tall fescues and perennial ryegrasses are the best options as they are resistant to HCB. Reducing thatch buildup should also lessen the severity of infestations.

Beauveria bassiana is a naturally occurring entomopathogenic fungus that can suppress HCB populations. Irrigation in spring and early summer helps to favor this fungus and promote its activity in the natural regulation of HCB. There is also a commercial formulation of *B. bassiana* that may be useful as an alternative to conventional chemical insecticides.

The traditional window for insecticidal control is mid-summer when HCB is most active. The optimal time is after overwintered adults have stopped laying eggs and before the nymphs from their earliest eggs have matured to adults. An alternative might be to target overwintered adults in early spring before they lay eggs. Before any chemical treatment, turf should be watered with 15-20 gallons water per 1000 sq. ft. Granular materials should be watered in after application.

More information online:

- entomology.unl.edu/turfent/documnts/chinchbg.shtml
- www.omafra.gov.on.ca/english/crops/facts/08-019.htm
- www.ento.psu.edu/extension/factsheets/chinchBugs.htm

6.2.5 Ants

Description and Natural history. Mound-building ants are nuisance pests of golf courses in the Northeast U.S. The most troublesome and widespread species is probably *Lasius neoniger*. This small, brown ant typically builds mounds that are concentrated around the edges of sand-based greens. A single nest may have several entrances, each with a squat volcano-shaped pile of soil. The main nest is usually located in the surrounding native soil. Mounds pushing up from within sand-based greens are typically the supplemental garrisons made by foraging workers. Mounding activity begins in early spring, increases through early summer, and declines by late summer at which point winged reproductive adults emerge and mate. Fertilized females then locate sites to overwinter and establish new colonies the following spring.

Decision-making. Monitoring for mound-building ants should begin with mid-summer mapping of problem areas across the golf course or other turf habitat. Then, early in the following growing season, monitor for ant activity in the areas that had high mound pressure the previous season. This is where control measures will need to be focused. Beyond greens, if mapping shows that the ants are moving in from golf course roughs, treatments can be targeted at the rough/fairway interface.

Intervention. Insecticides should only be expected to suppress, not eliminate, ant populations. Killing the colony's queen is difficult, and even if she dies, she can be replaced and the colony will persist. Ant colonies are most susceptible in the early season, when they are small and the queen is relatively weak from overwintering. When applied early, surface insecticides such as chlorpyrifos, can give 4-6 weeks suppression. Those applied later in season, however, may only offer 2-3 weeks suppression.

Insecticidal controls should focus on the perimeter of greens, collars, and roughs adjacent to main nests. This will best target the colony at the entrances to the main nest. An application made to the surface of the green itself will target the entrances of the auxiliary tunnels, but miss the main nest entrance that may be less visible in the higher-mown turf of the collar or rough.

There is mixed advice about using baits as part of a control program. The baits are granular products that contain insecticides and are broadcast applied on and around ant mounds in turf. They may be most effective when used after an initial knock-down application of a pyrethroid. However, the granule size of many baits may be too large and because these ants are generalists, the baits may not always attract them.

More information online:

- grounds-mag.com/golf_courses/grounds_maintenance_managing_nuisance_ants/index.html

6.2.6 Exotic Crane Flies

Description. Invasive European crane fly pests of turfgrass were detected for the first time in NY in 2004. Since then they have emerged as tremendously injurious insects. The larvae are the damaging life stage, commonly referred to as "leatherjackets" (although this may actually refer to the exuvium left behind when the adult emerges from the pupa). Two species, *Tipula paludosa* (the "European crane fly") and *Tipula oleracea* (the "common crane fly"), were originally detected in western NY. Both species are native to Europe but are now established in three geographic areas of North America: the Pacific Northwest (British Columbia, California, Oregon, Washington), eastern Canada (Newfoundland, Nova Scotia, Quebec), and the eastern Great Lakes (Massachusetts, Michigan, Ontario, New York). In NY, 2004 populations were only detected in Erie and Niagara counties. By 2010, *T. paludosa* had been detected in 11 counties (Chautauqua, Erie, Genesee, Monroe, Niagara, Oneida, Ontario, Orleans, Tompkins, Wayne, Wyoming), while *T. oleracea* had become more widespread, being detected in 18 counties (Broome, Cortland, Erie, Genesee, Livingston, Monroe, Nassau, Niagara, Oneida, Onondaga, Ontario, Orleans, Oswego, Seneca, Suffolk, Tompkins, Wayne, Wyoming). Based on these observations, there are probably two separate areas of establishment, the western Erie Canal corridor (both species) and Long Island (*T. oleracea*). Until we build awareness and establish safeguards to curtail range expansion, movement of infested materials could spread locally and regionally, across NY and into New England and the Mid-Atlantic.

Natural history. The majority of the crane fly lifecycle is spent in the damaging larval stage. The short-lived adults resemble oversized mosquitoes, but they do not feed and are non-damaging. Adults are 2.5-3.0 cm long, pupae 3.0-3.5 cm, mature larvae 3-4 cm and eggs 0.1 cm.

Tipula paludosa completes one generation a year, with the emergence of adults occurring over a period of 2-3 weeks at any one site in September and October. Adult females will emerge, mate and lay most of their eggs all within the first day of their brief reproductive lives, even though adults may persist for several days. Each female will deposit up to 200-300 black eggs at or near the soil surface; these eggs will hatch into larvae in about 10 days.

Larvae of *T. paludosa* develop through four instars before they pupate. Active larvae mostly inhabit the top 3 cm of the soil where they feed on root hairs, roots and crowns of grass host plants. Larger larvae will also emerge to forage on stems and grass blades on the soil surface. Larvae usually achieve third instar by the onset of winter. Most damage is attributed to the feeding of rapidly growing fourth instars in spring. By early to mid-June, larvae have achieved their maximum size and move 3-5 cm deep in the soil. They remain in a relatively non-feeding and inactive state until pupation, which ends when pupae wriggle to the surface so the adult fly can emerge. The empty pupal cases (exuviae, or the "jackets" of the leatherjackets) look like small grey-black twigs protruding from the turf where they can be spotted on low-mown grass such as golf course playing surfaces.

While the biology of *T. oleracea* is quite similar to *T. paludosa*, certain differences mean that management has to be tailored to the specific species. A major difference is that *T. oleracea* completes two generations a year, emerging in two peaks, one in spring (early May in western NY) and the other in autumn coinciding with *T. paludosa*. The larvae of *T. oleracea* never enter an inactive summer stage like *T. paludosa*. Larvae overwinter as fourth instars and pupation occurs in early spring. Adult *T. oleracea* differ from *T. paludosa* in being more capable fliers, with females laying eggs over the course of a few days.

Eggs of both species are sensitive to moisture and require wet conditions to hatch and survive. Larvae also do best under moist conditions, but once they are third and fourth instars they are quite tolerant of drought. Overall, mild winters and cool summers will probably favor crane fly populations. Other turf conditions such as thatch buildup, poor drainage and regular irrigation will likely favor crane fly survival and population buildup.

Diagnosis. There are hundreds of native crane fly species in NY and a few of them inhabit grassy habitats including turf. Native species are ostensibly non-damaging because none have been implicated in any turf injury in NY. Because of this, it is important to differentiate the injurious exotic species from the natives. The best physical character to separate them is based on wing pattern. Both exotic *Tipula* species have a narrow smoky band on the leading edge of the wing adjacent to a bordering whitish band. Unlike many native species, they have no other pigmentation on the wing. One widespread and locally abundant native species, however, is only differentiated because there is a break in the smoky band. Beyond that, characteristics of the male genitalia, ventral distance between the eyes, number of antennal segments, and length of the wing with respect to length of the abdomen permit the differentiation of exotic crane flies from native species, and also *T. paludosa* from *T. oleracea*. Nevertheless, species identification should be made or confirmed by a specialist.

Leatherjackets are serious pests of both low- and high-maintenance turf, from home lawns and golf courses to sod farms. Based on experience in the Pacific NW, pastures and grass seed fields can also be impacted. Spring densities of up to 70, 120 and 50 larvae/sq. ft. in highly damaged lawns, fairways and putting greens, respectively, have been recorded in the greater Buffalo and Rochester areas. Five categories of damage have been observed: nuisance populations of adult flies and larvae in suburban settings, thinning damage to home lawns, chewing damage to the surface of golf course putting greens, thinning and die-back on golf course fairways and rough, and vertebrate predation due to skunks and birds. In addition, it has been recently confirmed that larvae can survive harvest, transport and installation of sod. The movement of infested sod or other soil media will lead to new establishments and human-mediated range expansion.

Due to the relatively synchronous emergence of local adult populations, homeowners in suburban settings have experienced nuisance swarms of adults. Adults will settle on the sides of buildings, window screens and landscaping plants, and the public may mistake them for giant mosquitoes. In fact, the first reports of invasive crane flies for both Long Island and the Rochester area were made by homeowners. High larval densities may also act as nuisance populations as rain showers can wash them off sloped lawns and amass them as piles of maggots in culverts.

On affected home lawns and golf course fairways, root pruning leads to white grub-like damage. The disruption of the rooting zone promotes rapid die-off when the injured turf is drought-stressed. Another expression of injury is extreme thinning due to surface feeding. Early to mid-May is when injury is most likely to be expressed by *T. paludosa* because large larvae are feeding rapidly as they approach the end of development. On affected golf course putting greens, foliar feeding by larvae on crowns and leaf blades causes damage akin to black cutworms. Larvae will reside in aerification holes or in self-made burrows from which they emerge to forage, chewing shallow quarter-sized pits into the playing surface.

Monitoring. To detect the presence of invasive crane flies, the leathery pupal cases can be monitored on tees, greens and fairways where they protrude from the low-mown turf. At times of peak emergence, the adults are abundant and highly visible as they flit about low in the grass. Adults may also congregate during the day on the sides of buildings, sliding doors, window screens and fences. Because adults lay eggs so soon after emergence, they do not move far from the sites where larvae developed. Therefore, sites with abundant adults, larvae or pupal cases should be monitored as an indication of sites where eggs of the next generation are likely to be laid. If a crane fly infestation is suspected, send adults, larvae or pupal cases to a specialist for proper identification.

If signs of insect activity and turfgrass injury suggest leatherjackets, core sampling is the best way to detect and sample larvae. Larvae can be monitored in the late autumn or early spring. Take samples with a cup cutter and rip apart the core to look for larvae. Traditional soap-based disclosing solutions (see 6.2.2) are not effective at driving larvae to the surface. Certain insecticides such as pyrethroids and carbamates, however, will reveal the presence of larvae because many will move to the surface before dying, often within 1-12 hours. This approach is most effective when soil water content is high and insecticides can readily penetrate the soil surface.

Decision-making. Control tactics should be directed against the larvae because adults are hard to target and short-lived. Depending on the overall health of the turf, suggested thresholds are 15-50 larvae/sq. ft. Autumn populations are likely to surpass these thresholds, but it is important to keep in mind that leatherjackets can suffer very high mortality between late autumn and early spring due to winter stress and predation by birds and other vertebrates. Vigorous turf can therefore support relatively high population levels in autumn and visible damage is highly unlikely.

Intervention – Cultural control. Because of their relative sensitivity to dry conditions, careful manipulation of soil moisture levels may be a key cultural tactic to reduce populations. Some strategies might be to regulate the timing and frequency of irrigation, particularly during the oviposition period, to better drain chronically infested areas and to allow the sward to dry (i.e., avoiding irrigation) in autumn. Maintaining a vigorous stand that is more tolerant to infestation might also alleviate problems.

Intervention – Chemical control. The two main control windows are late autumn and early spring. Since adults of both species emerge during a similar window in September, small larvae of both species would be susceptible to preventive insecticides. Therefore, a late autumn preventive application is recommended if populations of both species occur at the same site. Timing should be after peak emergence of adults in order to overlap the period of egg hatch and first instars.

Otherwise, curative applications for *T. paludosa* can be made in early spring after scouting reveals populations or once feeding damage is detected. *Tipula oleracea* is probably not susceptible during this window because it pupates early in spring and insecticides are not active against pupae.

The aforementioned control windows, unfortunately, do not coincide with other turfgrass pests. The arrival and spread of these exotics thereby represents a worrisome new economic burden for turfgrass managers. To identify the best chemistries for invasive crane fly control in NY, a series of field efficacy trials has been conducted against *T. paludosa*. Based on consistency and efficacy, a series of chemistries is acceptable for preventive late autumn control, including bifenthrin, carbaryl, chlorantraniliprole, imidacloprid, indoxacarb and trichlorfon. Among the best products for curative spring control are carbaryl, chlorpyrifos, imidacloprid and trichlorfon. Overall, insecticidal efficacy declines from autumn to spring as the larvae grow larger.

Intervention – Biological control. In addition to registered chemical insecticides, a registered biological control option is *Beauveria bassiana*, an entomopathogenic fungus. The entomopathogenic nematode, *Steinernema carpocapsae,* is another biological alternative that has been promoted in the Northwest.

More information online:

Northeast:

- www.nysipm.cornell.edu/factsheets/turfgrass/default.asp

Pacific Northwest:

- www.ipm.ucdavis.edu/PMG/r785301411.html
- whatcom.wsu.edu/cranefly

6.3 Turfgrass Insecticides

6.3.1 Insecticide Resistance and IRAC Codes

The Insecticide Resistance Action Committee (IRAC) is an international group of 150+ members of the Crop Protection Industry organized by sector and region to advise on the prevention and management of insecticide resistance. This group assigns codes, based on mode of action, to individual insecticide active ingredients in order to facilitate resistance management – just like the FRAC and WSSA codes for fungicides and herbicides (respectively). Turfgrass managers should be mindful of the frequency of using insecticides in the same class, having the same IRAC code. More information about IRAC and insecticide modes of action, as well as an interactive classification look-up tool, can be found at www.irac-online.org. In addition, the IRAC codes for all turfgrass insecticides mentioned in these guidelines are listed in table 9 at the back of this book.

Table 6.3.1 – Pesticides labeled for Annual bluegrass weevil

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
azadirachtin (Ornazin 3% Botanical Insecticide)	10 oz/acre	L	12	UN	0	
azadirachtin (AzaGuard)	10-16 fl oz/acre	L	4	UN	0 - 0	
Beauvaria bassiana (Botanigard ES)	2-5 fl oz/1000 sq ft	A	4	NC	Not Available	Botanigard ES is synergistic with bifenthrin against adult weevils. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Golf courses only. 2(ee) recommendation for use in tank mix with bifenthrin.
*beta-cyfluthrin (Tempo Ultra GC Insecticide)	12 fl oz/acre	A	-	3A	3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
bifenthrin (Andersons Golf Products 0.15G Prosect)	33-133 lb/acre	A	-	3A	2 - 9	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
bifenthrin (Menace GC)	10-20 oz/acre	A	-	3A	2 - 4	See label for specific setback distances from water bodies. Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms in the state of New York.
[Δ]bifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	87-174 lb/acre	A	-	3A + 1A	48 - 95	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Sevin SL Carbaryl Insecticide)	8 qt/acre	L	24	1A	163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried.
[*NY]†chlorantraniliprol e (Acelepryn)	12-20 fl oz/acre	L	4	28	3 - 4	See label for specific setback distances from water bodies. Not for use in Nassau, Suffolk, Kings, or Queens Counties in NY.

Table 6.3.1 – Pesticides labeled for Annual bluegrass weevil

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
chlorpyrifos (Andersons Golf Products Insecticide III)	1.7 lbs/1000 sq ft	A	-	1B	27	
*NYcyantraniliprole (Ference)	12-20 fl oz/acre	L	-	28	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Do not use on turf grown for seed production. Not for sale, sale into, distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State.
deltamethrin (Suspend SC Insecticide)	26-39 fl oz/acre	A	-	3A	2 - 3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
*NYimidacloprid (GrubEx Pro)	1.25 to 1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NYimidacloprid (Merit 2F Insecticide)	1.25-1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NYimidacloprid (Merit 75 WP)	6.4 to 8.6 oz/acre	L	12	4	11 - 15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*NYimidacloprid (Armortech IMD 75)	6.4–8.6 oz/acre	L	-	4	11 - 15	Do not use this product on commercial sod farms. Do not apply to areas which are water logged or saturated. This product comes in a water soluble packet; do not use partial packets.
*NYimidacloprid, bifenthrin (Bithor SC)	3.6-4.5 pt/acre	A	-	4 + 3A	14 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
*NYlambda-cyhalothrin (Cyonara 9.7 Insecticide)	10 fl oz/acre	A	-	3	3	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. See label for specific setback distance restrictions from water bodies. Not for use on sod farms, in seed production, or for research.
*NYlambda-cyhalothrin (Demand EZ Insecticide)	40 fl oz/acre	A	-	3	3	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on golf courses, sod farms, or in seed production. Do not apply or allow to drift on to plants

Table 6.3.1 – Pesticides labeled for Annual bluegrass weevil

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						in bloom if bees are visiting the treatment area.
*lambda-cyhalothrin (Scimitar GC Insecticide)	10 fl oz/acre	A	24	3A	3	Do not apply to areas which are water logged or saturated.
spinosad (Conserve SC Turf and Ornamental)	52 fl oz/acre	L	4	5	6	See label for specific resistance management requirements.
trichlorfon (Dylox 420SL Turf and Ornamental Insecticide)	225-300 fl oz/acre	L A	Until Dry	1B	110 - 147	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on sod farms or turf being grown for commercial seed.
zeta-cypermethrin (Amdro Quick Kill Lawn & Landscape Insect Killer Concentrate)	7.5 fl oz per 1000 sq ft			3A	Not Available	Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.2 – Pesticides labeled for Black turfgrass ataenius

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
azadirachtin (Ornazin 3% Botanical Insecticide)	8 oz/acre	L	12	UN	0	
azadirachtin (AzaGuard)	8-16 fl oz/acre	L	4	UN	0 - 0	
Beauvaria bassiana (Botanigard 22 WP)	1-4 oz/1000 sq ft	L	4	NC	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
Beauvaria bassiana (Botanigard ES)	2-8 fl oz/1000 sq ft	L A	4	NC	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*beta-cyfluthrin (Tempo Ultra GC Insecticide)	12 fl oz/acre	A	-	3A	3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod

Table 6.3.2 – Pesticides labeled for Black turfgrass ataenius

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						farms or turf being grown for commercial seed.
bifenthrin (Andersons Golf Products 0.15G Prosect)	33-133 lb/acre	A	-	3A	2 - 9	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
bifenthrin, carbaryl (Andersons Golf Products Duocide Insect Control)	87-174 lb/acre broadcast	A	-	3A + 1A	48 - 95	Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York.
bifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	87-174 lb/acre	A	-	3A + 1A	48 - 95	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl)	2.4 lbs/1000 sq ft	L	-	1A	190	Not for use on sod farms or turf being grown for commercial seed.
carbaryl (Sevin SL Carbaryl Insecticide)	8 qt/acre	L	24	1A	163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried.
*NY cyantraniliprole (Ference)	8-16 fl oz/acre	L	-	28	Not Availab le	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Do not use on turf grown for seed production Not for sale, sale into, distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State. Applications targeting larvae should be made from peak adult flight through peak egg hatch to ensure control of the first-generation larvae.
deltamethrin (Suspend SC Insecticide)	26-39 fl oz/acre	A	-	3A	2 - 3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
*NY imidacloprid (Armortech IMD 75)	6.4–8.6 oz/acre	L	-	4	11 - 15	Do not use this product on commercial sod farms. Do not apply to areas which are water logged or saturated. This product comes in a

Table 6.3.2 – Pesticides labeled for Black turfgrass ataenius

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						water soluble packet; do not use partial packets.
*NY imidacloprid (GrubEx Pro)	1.25 to 1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NY imidacloprid (Merit 2F Insecticide)	1.25-1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NY imidacloprid (Merit 75 WP)	6.4 to 8.6 oz/acre	L	12	4	11 - 15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*NY imidacloprid, bifenthrin (Bithor SC)	3.6-4.5 pt/acre	L	-	4 + 3A	14 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
*NY lambda-cyhalothrin (Cyonara 9.7 Insecticide)	10 fl oz/acre	A	-	3	3	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. See label for specific setback distance restrictions from water bodies. Not for use on sod farms, in seed production, or for research.
*NY lambda-cyhalothrin (Demand EZ Insecticide)	40 fl oz/acre	A	-	3	3	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on golf courses, sod farms, or in seed production. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*lambda-cyhalothrin (Scimitar GC Insecticide)	10 fl oz/acre	A	24	3A	3	Do not apply to areas which are water logged or saturated.
spinosad (Conserve SC Turf and Ornamental)	52 fl oz/acre	A	4	5	6	See label for specific resistance management requirements.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.3 – Pesticides labeled for Bluegrass billbug

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
azadirachtin (Ornazin 3% Botanical Insecticide)	10 oz/acre	L	12	UN	0	
azadirachtin (AzaGuard)	10-16 fl oz/acre	L	4	UN	0 - 0	
Beauvaria bassiana (Botanigard 22 WP)	1-4 oz/1000 sq ft	A	4	NC	Not Availab le	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*beta-cyfluthrin (Tempo Ultra GC Insecticide)	12 fl oz/acre	A	-	3A	3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
bifenthrin (Andersons Golf Products 0.15G Prosect)	33-133 lb/acre	A	-	3A	2 - 9	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
bifenthrin (Menace GC)	10-20 oz/acre	A	-	3A	2 - 4	See label for specific setback distances from water bodies. Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms in the state of New York.
Δbifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	87-174 lb/acre	A	-	3A + 1A	48 - 95	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl)	2.4 lbs/1000 sq ft	L	-	1A	190	Not for use on sod farms or turf being grown for commercial seed.
carbaryl (Sevin SL Carbaryl Insecticide)	8 qt/acre	L	24	1A	163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried.
*NY†chlorantraniliprole (Acelepryn)	8-20 fl oz/acre	L	4	28	2 - 4	See label for specific setback distances from water bodies. Not for

Table 6.3.3 – Pesticides labeled for Bluegrass billbug

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						use in Nassau, Suffolk, Kings, or Queens Counties in NY.
chlorpyrifos (Andersons Golf Products Insecticide III)	1.7 lbs/1000 sq ft	L A	-	1B	27	
*NY cyantraniliprole (Ference)	8-16 fl oz/acre	L	-	28	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Do not use on turf grown for seed production. Not for sale, sale into, distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State.
deltamethrin (Suspend SC Insecticide)	26-39 fl oz/acre	A	-	3A	2 - 3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
*NY imidacloprid (GrubEx Pro)	1.25 to 1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NY imidacloprid (Merit 2F Insecticide)	1.25-1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NY imidacloprid (Merit 75 WP)	6.4 to 8.6 oz/acre	L	12	4	11 - 15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*NY imidacloprid, bifenthrin (Bithor SC)	1.1-4.5 pt/acre	A	-	4 + 3A	4 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
*NY lambda-cyhalothrin (Cyonara 9.7 Insecticide)	10 fl oz/acre	A	-	3	3	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. See label for specific setback distance restrictions from water bodies. Not for use on sod farms, in seed production, or for research.
*NY lambda-cyhalothrin (Demand EZ Insecticide)	40 fl oz/acre	A	-	3	3	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on golf courses, sod farms, or in seed production. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.

Table 6.3.3 – Pesticides labeled for Bluegrass billbug

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
*lambda-cyhalothrin (Scimitar GC Insecticide)	10 fl oz/acre	A	24	3A	3	Do not apply to areas which are water logged or saturated.
permethrin (Howard Johnson's Permethrin)	2.5 lbs/1000 sq ft	A	-	3A	8	
trichlorfon (Dylox 420SL Turf and Ornamental Insecticide)	300 fl oz/acre	L	Until Dry	1B	147	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on sod farms or turf being grown for commercial seed.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate ‘Not for use on Long Island, NY’ mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.4 – Pesticides labeled for Chinch bug

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
*NYacephate (Acephate 90 WDG)	2.71-4.44 lb/acre		-	1B	61 - 99	For use on golf courses only. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
azadirachtin (AzaGuard)	10-16 fl oz/acre		4	UN	0 - 0	
azadirachtin (Ornazin 3% Botanical Insecticide)	10 oz/acre		12	UN	0	
Beauvaria bassiana (Botanigard 22 WP)	1-4 oz/1000 sq ft		4	NC	Not Availabl e	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
Beauvaria bassiana (Botanigard ES)	2-8 fl oz/1000 sq ft		4	NC	Not Availabl e	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*beta-cyfluthrin (Tempo Ultra GC Insecticide)	12 fl oz/acre		-	3A	3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
bifenthrin (Andersons Golf Products 0.15G Prosect)	33-266 lb/acre		-	3A	2 - 18	See label for specific setback distances from water bodies. Not for use on golf

Table 6.3.4 – Pesticides labeled for Chinch bug

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						courses, sod farms, or in seed production.
bifenthrin (Menace GC)	10-20 oz/acre		-	3A	2 - 4	See label for specific setback distances from water bodies. Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms in the state of New York.
^Δ^bifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	87-174 lb/acre		-	3A + 1A	48 - 95	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl)	1.7-2.4 lbs/1000 sq ft		-	1A	135 - 190	Not for use on sod farms or turf being grown for commercial seed.
carbaryl (Sevin SL Carbaryl Insecticide)	6-8 qt/acre		24	1A	122 - 163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried.
*NY†chlorantraniliprole (Acelepryn)	8-20 fl oz/acre		4	28	2 - 4	See label for specific setback distances from water bodies. For suppression only. Not for use in Nassau, Suffolk, Kings, or Queens Counties in NY.
chlorpyrifos (Andersons Golf Products Insecticide III)	1.7 lbs/1000 sq ft		-	1B	27	
*NYcyantraniliprole (Ference)	8-20 fl oz/acre		-	28	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. For suppression only. Do not use on turf grown for seed production. Not for sale, sale into, distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State.
deltamethrin (Suspend SC Insecticide)	26-39 fl oz/acre		-	3A	2 - 3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.

Table 6.3.4 – Pesticides labeled for Chinch bug

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
[*NY]imidacloprid (Armortech IMD 75)	8.6 oz/acre		-	4	15	Do not use this product on commercial sod farms. Do not apply to areas which are water logged or saturated. For suppression only. This product comes in a water soluble packet; do not use partial packets.
[*NY]imidacloprid (GrubEx Pro)	1.6 pt/acre		12	4	13	Do not apply to areas which are water logged or saturated. For suppression only.
[*NY]imidacloprid (Merit 2F Insecticide)	1.6 pt/acre		12	4	13	Do not apply to areas which are water logged or saturated. For suppression only.
[*NY]imidacloprid (Merit 75 WP)	8.6 oz/acre		12	4	15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. For suppression only.
[*NY]imidacloprid, bifenthrin (Bithor SC)	1.1-4.5 pt/acre		-	4 + 3A	4 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
permethrin (Howard Johnson's Permethrin)	2 lbs/1000 sq ft		-	3A	6	
trichlorfon (Dylox 420SL Turf and Ornamental Insecticide)	300 fl oz/acre		Until Dry	1B	147	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on sod farms or turf being grown for commercial seed.
zeta-cypermethrin (Amdro Quick Kill Lawn & Landscape Insect Killer Concentrate)	7.5 fl oz per 1000 sq ft			3A	Not Available	Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area. See label for where this product can be used.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.5 – Pesticides labeled for European crane fly

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
azadirachtin (AzaGuard)	10-16 fl oz/acre	L	4	UN	0 - 0	
azadirachtin (Ornazin 3% Botanical Insecticide)	10 oz/acre	L	12	UN	0	
bifenthrin (Andersons Golf Products 0.15G Prosect)	33-266 lb/acre	L	-	3A	2 - 18	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
bifenthrin (Menace GC)	10-20 oz/acre	L	-	3A	2 - 4	See label for specific setback distances from water bodies. Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms in the state of New York.
Δbifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	174-348 lb/acre	L	-	3A + 1A	95 - 191	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY. For adult control.
carbaryl (Sevin SL Carbaryl Insecticide)	8 qt/acre	L	24	1A	163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried.
carbaryl (Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl)	2.4 lbs/1000 sq ft	L	-	1A	190	Not for use on sod farms or turf being grown for commercial seed.
*NY†chlorantraniliprole (Acelepryn)	8-16 fl oz/acre	L	4	28	2 - 4	See label for specific setback distances from water bodies. For suppression only. Not for use in Nassau, Suffolk, Kings, or Queens Counties in NY.
*NYcyantraniliprole (Ference)	12-16 fl oz/acre	L	-	28	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Do not use on turf grown for seed production. Not for sale, sale into, distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State.
*NYimidacloprid (Armortech IMD 75)	6.4–8.6 oz/acre	L	-	4	11 - 15	Do not use this product on commercial sod farms. Do not apply to areas which are water logged or saturated. This

Table 6.3.5 – Pesticides labeled for European crane fly

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						product comes in a water soluble packet; do not use partial packets.
*NYimidacloprid (GrubEx Pro)	1.25 to 1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NYimidacloprid (Merit 2F Insecticide)	1.25-1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated.
*NYimidacloprid (Merit 75 WP)	6.4 to 8.6 oz/acre	L	12	4	11 - 15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*NYimidacloprid, bifenthrin (Bithor SC)	3.6-4.5 pt/acre	L	-	4 + 3A	14 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.6 – Pesticides labeled for Lawn caterpillars

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
*NYacephate (Acephate 90 WDG)	1.1-4.44 lb/acre		-	1B	25 - 99	For use on golf courses only. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
azadirachtin (AzaGuard)	8-21 fl oz/acre	L	4	UN	0 - 0	
azadirachtin (Ornazin 3% Botanical Insecticide)	8 oz/acre	L	12	UN	0	
Bacillus thuringinensis subsp. Kurstaki (Javelin WG)	1 lb/acre	L	4	11A	11	This product must not be applied aerially within 1/4 mile of any habitats of endangered or threatened Lepidoptera. No manual application can be made within 300ft. of any threatened or endangered Lepidoptera.
Bacillus thuringinensis subsp. Kurstaki (Crymax)	0.5-2 lb/acre	L	4	11A	3 - 11	This product must not be applied aerially within 1/4 mile of any habitats of endangered or threatened Lepidoptera. No manual application can be made within 300ft. of any threatened or

Table 6.3.6 – Pesticides labeled for Lawn caterpillars

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						endangered Lepidoptera. Armyworm, sod webworm only.
*beta-cyfluthrin (Tempo Ultra GC Insecticide)	6-12 fl oz/acre	L	-	3A	1 - 3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
bifenthrin (Andersons Golf Products 0.15G Prosect)	33-66 lb/acre	L	-	3A	2 - 4	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
bifenthrin (Menace GC)	10-20 oz/acre	L	-	3A	2 - 4	See label for specific setback distances from water bodies. Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms in the state of New York.
^Δ^bifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	87 lb/acre	L	-	3A + 1A	48	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Sevin SL Carbaryl Insecticide)	2-8 qt/acre	L	24	1A	41 - 163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried. See label for specific rate depending on pest controlled.
carbaryl (Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl)	1.7-2.4 lbs/1000 sq ft	L	-	1A	135 - 190	Not for use on sod farms or turf being grown for commercial seed.
*NY†chlorantraniliprole (Acelepryn)	2-4 fl oz/acre	L	4	28	0 - 1	See label for specific setback distances from water bodies. For suppression only. Not for use in Nassau, Suffolk, Kings, or Queens Counties in NY.
chlorpyrifos (Andersons Golf Products Insecticide III)	1.7 lbs/1000 sq ft	L	-	1B	27	
*NYcyantraniliprole (Ference)	2-16 fl oz/acre	L	-	28	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Do not use on turf grown for seed production. Not for sale, sale into,

Table 6.3.6 – Pesticides labeled for Lawn caterpillars

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State.
deltamethrin (Suspend SC Insecticide)	17.5-26 fl oz/acre	L	-	3A	2 - 2	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
*NYimidacloprid (Armortech IMD 75)	8.6 oz/acre	L	-	4	15	Do not use this product on commercial sod farms. Do not apply to areas which are water logged or saturated. This product comes in a water soluble packet; do not use partial packets. Labeled only for cutworms (suppression).
*NYimidacloprid (GrubEx Pro)	1.25 to 1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated. Cutworm suppression only.
*NYimidacloprid (Merit 2F Insecticide)	1.25-1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated. Not labeled for armyworm or sod webworm. Cutworm suppression only.
*NYimidacloprid (Merit 75 WP)	6.4 to 8.6 oz/acre	L	12	4	11 - 15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not labeled for armyworm or sod webworm. Cutworm suppression only.
*NYimidacloprid, bifenthrin (Bithor SC)	1.1-4.5 pt/acre	L	-	4 + 3A	4 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
*NYlambda-cyhalothrin (Cyonara 9.7 Insecticide)	5-10 fl oz/acre	L	-	3	1 - 3	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. See label for specific setback distance restrictions from water bodies. Not for use on sod farms, in seed production, or for research.
*NYlambda-cyhalothrin (Demand EZ Insecticide)	20-40 fl oz/acre	L	-	3	1 - 3	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on golf courses, sod farms, or in seed production. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*lambda-cyhalothrin (Scimitar GC Insecticide)	5-10 fl oz/acre	L	24	3A	1 - 3	Do not apply to areas which are water logged or saturated.

Table 6.3.6 – Pesticides labeled for Lawn caterpillars

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
permethrin (Howard Johnson's Permethrin)	2 lbs/1000 sq ft	L	-	3A	6	
spinosad (Conserve SC Turf and Ornamental)	10-52 fl oz/acre	L	4	5	1 - 6	See label for specific resistance management requirements. See label for specific rate depending on pest controlled.
trichlorfon (Dylox 420SL Turf and Ornamental Insecticide)	200-300 fl oz/acre	L	Until Dry	1B	98 - 147	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on sod farms or turf being grown for commercial seed.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.7 – Pesticides labeled for Mound-building ants

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
*beta-cyfluthrin (Tempo Ultra GC Insecticide)	0.135-0.270 fl oz/1000 sq ft	A	-	3A	1 - 3	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
bifenthrin (Andersons Golf Products 0.15G Prosect)	133-266 lb/acre	A	-	3A	9 - 18	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
bifenthrin (Menace GC)	0.23-0.46 oz/1000 sq ft	A	-	3A	2 - 4	See label for specific setback distances from water bodies. Do not use this product on golf courses and sod farms in Nassau County or Suffolk County, New York. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms in the state of New York.
Δbifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	174-348 lb/acre	A	-	3A + 1A	95 - 191	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Andersons Prof. Turf Products 8% Granular	1.7-2.4 lbs/1000 sq ft	A	-	1A	135 - 190	Not for use on sod farms or turf being grown for commercial seed.

Table 6.3.7 – Pesticides labeled for Mound-building ants

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
Insecticide w/Carbaryl)						
carbaryl (Sevin SL Carbaryl Insecticide)	2-4 qt/acre	A	24	1A	41 - 81	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried. Will only kill pests that are present at the time of application and directly contacted by product.
chlorpyrifos (Andersons Golf Products Insecticide III)	1.7 lbs/1000 sq ft	A	-	1B	27	
deltamethrin (Suspend SC Insecticide)	0.4-0.6 fl oz/1000 sq ft	A	-	3A	2 - 2	See label for specific setback distances from water bodies. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Not for use on sod farms or turf being grown for commercial seed.
indoxacarb (Dupont Advion Insect Granule)	1.15-4.6 lbs/1000 sq ft	A	-	22A	3 - 14	Not for use on sod farms or turf being grown for commercial seed.
*NYlambda-cyhalothrin (Cyonara 9.7 Insecticide)	.115-.236 fl oz/1000 sq ft	A	-	3	1 - 3	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. See label for specific setback distance restrictions from water bodies. Not for use on sod farms, in seed production, or for research.
*NYlambda-cyhalothrin (Demand EZ Insecticide)	.46-.94 fl oz/1000 sq ft	A	-	3	Not Available	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on golf courses, sod farms, or in seed production. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
*lambda-cyhalothrin (Scimitar GC Insecticide)	3.4-7 ml/1000 sq ft	A	24	3A	Not Available	Do not apply to areas which are water logged or saturated.
permethrin (Howard Johnson's Permethrin)	2 lbs/1000 sq ft	A	-	3A	6	

Table 6.3.7 – Pesticides labeled for Mound-building ants

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
zeta-cypermethrin (Amdro Quick Kill Lawn & Landscape Insect Killer Concentrate)	.8 fl oz/1-2 gal water			3A	Not Availabl e	Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area. See label for where this product can be used. Apply to each mound by sprinkling mound until wet, then treat a 4 foot diameter circle around the mound.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate ‘Not for use on Long Island, NY’ mean that use is prohibited in Nassau and Suffolk Counties only.

Table 6.3.8 – Pesticides labeled for White grubs

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
azadirachtin (AzaGuard)	8-21 fl oz/acre	L	4	UN	0 - 0	
Bacillus thuringiensis subs galleriea (Grubgone!G)	100-150 lb/acre	L	4	11A	Not Available	
Beauvaria bassiana (Botanigard ES)	2-8 fl oz/1000 sq ft	L	4	NC	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
Beauvaria bassiana (Botanigard 22 WP)	1-4 oz/1000 sq ft	L	4	NC	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area.
Δbifenthrin, carbaryl (Andersons Turf Products Duocide Insect Control)	87-174 lb/acre preventative; 174-348 lb/acre preventative	L	-	3A + 1A	48 - 95	Not for use on golf courses, sod farms, or in seed production. Do not apply within 100 feet of a water body in NY.
carbaryl (Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl)	2.4 lbs/1000 sq ft	L	-	1A	190	Not for use on sod farms or turf being grown for commercial seed.
carbaryl (Sevin SL Carbaryl Insecticide)	8 qt/acre	L	24	1A	163	Broadcast applications to turfgrass are permitted only on golf courses, sod farms, cemeteries, and commercial landscapes. Applications to all other lawns or turf (residential settings) are limited

Table 6.3.8 – Pesticides labeled for White grubs

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
						to spot treatments. Do not allow public use of treated areas during applications or until sprays have dried.
*NY†chlorantraniliprole (Acelepryn)	8-16 fl oz/acre	L	4	28	2 - 4	See label for specific setback distances from water bodies. For suppression only. Not for use in Nassau, Suffolk, Kings, or Queens Counties in NY.
*NYcyantraniliprole (Ference)	8-20 fl oz/acre	L	-	28	Not Available	Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. Do not use on turf grown for seed production. Not for sale, sale into, distribution and/or use in Nassau, Suffolk, Kings, Queens counties of New York State.
Heterorhabditis bacteriophora (NemaSeek)	10 million /3200 sq ft	L	-	NC	Not Available	
*NYimidacloprid (Armortech IMD 75)	6.4–8.6 oz/acre	L	-	4	11 - 15	Do not use this product on commercial sod farms. Do not apply to areas which are water logged or saturated. For optimum control make application prior to egg hatch. This product comes in a water soluble packet; do not use partial packets.
*NYimidacloprid (GrubEx Pro)	1.25 to 1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated. For optimum control make application prior to egg hatch.
*NYimidacloprid (Merit 2F Insecticide)	1.25-1.6 pt/acre	L	12	4	10 - 13	Do not apply to areas which are water logged or saturated. For optimum control make application prior to egg hatch.
*NYimidacloprid (Merit 75 WP)	6.4 to 8.6 oz/acre	L	12	4	11 - 15	Do not apply to areas which are water logged or saturated. Do not apply or allow to drift on to plants in bloom if bees are visiting the treatment area. For optimum control make application prior to egg hatch.
*NYimidacloprid, bifenthrin (Bithor SC)	3.6-4.5 pt/acre	L	-	4 + 3A	14 - 17	See label for specific setback distances from water bodies. Not for use on golf courses, sod farms, or in seed production.
Paenibacillus popilliae (Milky Spore Powder)	10 oz/2500 sq ft	L	-	NC	Not Available	Japanese beetle grubs only.

Table 6.3.8 – Pesticides labeled for White grubs

Active Ingredient (Trade Name)	Product Rate	Life Stage[1]	REI[2] (Hours)	IRAC[3]	Field Use EIQ[4]	Comments
trichlorfon (Dylox 420SL Turf and Ornamental Insecticide)	300 fl oz/acre	L	Until Dry	1B	147	See label for specific setback distances from water bodies. Do not apply to areas which are water logged or saturated. Not for use on sod farms or turf being grown for commercial seed.

[1]Life stage, A = Adult, L = Larvae, N = Nymph
[2]REI - Restricted Entry Interval. Only pertains to agricultural uses of the product.
[3]IRAC - Resistance management codes according to active ingredient mode of action assigned by the Insecticide Resistance Action Committee (www.irac-online.org)
[4]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

7 Weed Management

7.1 The Basics of Weeds

A weed is any plant that is out of place. In turf landscapes, the tolerance for weeds is dependent on the type of land use and client preferences. Low tolerance for weeds is expected for golf courses and competitive sports fields, while lawns, parks, and school grounds allow a greater range in acceptability. Environmentally compatible weed management begins with an understanding of turfgrass visual and functional performance expectations in an effort to develop an integrated weed management program. Defining the threshold for weed tolerance is essential in determining appropriate weed management strategies.

Functionally, weeds can reduce the playability and safety of golf and sports turf. Weeds could disrupt the footing of an athletic sports field and alter the lie and roll of a golf ball, thereby disrupting the fairness of a golf game. These disruptions can have health as well as economic effects on turfgrass facilities. Weeds are more of an aesthetic problem in parks, school grounds, and lawns, as playability and safety are less of a concern.

Severe weed infestations requiring some type of control measure are often associated with less than adequate growing conditions (light, water, air movement), excessive traffic, improper culture, and failure to manage other pests such as diseases and insects. As a rule, weeds will invade when turfgrass is not maintained in a healthy and vigorous condition, maximizing its competitive ability.

7.1.1 Herbicide Resistance and WSSA Classifications

The Weed Science Society of America (WSSA) classifies herbicides by their Mechanism of Action to help manage plant resistance to herbicides. These classifications are homologous to the FRAC and IRAC codes for fungicides and insecticides (respectively). Turfgrass managers should be mindful of the frequency of using herbicides in the same classification, having the same WSSA code. More information about the WSSA, herbicide mechanisms of action, and resistance management can be found at www.wssa.net/Weeds/Resistance/index.htm. In addition, the WSSA codes for all turfgrass herbicides mentioned in these guidelines are listed in table 9 at the back of this book.

7.1.2 Integrated Weed Management

For many years, the turfgrass industry has been implementing a broad based decision-making management system known as Integrated Pest Management (IPM). IPM has evolved since its inception to more completely embrace the importance of turf culture that maximizes plant health. Still, misconceptions persist regarding the more traditional aspects of IPM such as "using only biological control" and "no use of pesticides".

The misconceptions of IPM pose a unique challenge from a weed management perspective. Visual thresholds are subjective (some like the look of weeds, some don't), functional thresholds are exceptionally low or not known (how many weeds can an athletic field have before the game is disrupted?) and there are no effective biological controls once the weed is established. Therefore, the most effective IPM program for weed management is prevention by maintaining turfgrass density.

7.2 Starting Out Right

Maintaining a competitive turf begins with proper grass selection and establishment. Improper site preparation, poor timing, and improper maintenance leave the turf area vulnerable to weed infestation.

When using turfgrass sod, be aware that there have been issues with annual bluegrass and creeping bentgrass contaminating the sod in the field. Be sure to specify annual bluegrass-free sod or bentgrass-free sod if using Kentucky bluegrass or other mixtures.

In addition to contaminated sod, contaminated seed could be a source of weeds such as *Poa trivialis*. There is evidence that *Poa trivialis* grows naturally and seeds or stolons can germinate after lying dormant. It is entirely possible that it is introduced as a contaminant in turf seed. Seed producers have since self-imposed *Poa trivialis* growing and shipping restrictions to help prevent this.

Another important weed management practice during establishment is timing your seeding to avoid specific weed problems. For most cool season turfgrass stands, this is the reason late summer to early fall is an ideal time to seed as most weeds are less competitive at this time. Annual weeds dieback in the fall, leaving gaps in the turf. Reseeding these areas with turf helps prevent weed germination in the spring. If annual bluegrass is your primary concern, as it is on most golf courses, then it is best to seed in late June and July when annual bluegrass germination is significantly reduced.

For more information on maintaining a competitive turf stand, see section 2 on Turfgrass Culture.

A few chemical herbicides can be used at or during establishment to reduce weed competition such as preemergence siduron and postemergence fenoxaprop and bromoxynil applications. There are significant species restrictions for the postemergence products, so be sure to read the label carefully.

7.2.1 Herbicide Use at Seeding

Preventing weed invasion in turf is a more effective strategy than controlling established weeds.
Tenacity is an herbicide product from Syngenta classified as Reduced Risk. It was inspired by the lemon bottlebrush plant that produces leptospermone as an allelopathic substance; the mesotrione molecule is based on leptospermone. For use in the seedbed at 4-6 fl. oz./A it will be a very strong competitor with Tupersan. It can be used the day of seeding with Kentucky bluegrass for preemergence crabgrass and some broadleaf. There are rate restrictions for use on fine fescue seedling turf.

The use of Tenacity for weed control in the seedbed is expanding as additional research and field use has increased. Several studies are showing excellent annual bluegrass suppression when used at the time of seeding. Additional research has found that split applications at establishment at the 2.5 and 3.0 fluid ounces per acre provided 100 percent broadleaf weed control four months after establishing a Kentucky bluegrass/perennial ryegrass seed mixture. Furthermore, there was evidence that Tenacity provided excellent yellow nutsedge control.

This technology offers sports turf managers exceptional benefit when dealing with high traffic areas and the need for overseeding. Regular applications of Tenacity in conjunction with overseeding will reduce weed competition and likely improve turf stand establishment.

7.3 Annual Grass Control

A well maintained turfgrass area provides many aesthetic and functional benefits. Decades of scientific research have been conducted to aid with management that maximizes plant health and minimizes environmental impact. Significant concern for environmental quality and human health has raised public awareness and led to increased scrutiny of management practices, especially pest management.

The role of turfgrass density is critical for IPM, as well as for maximizing the environmental benefits of turf. For example, studies from university research have indicated that a thin, unfertilized turf resulted in greater nutrient runoff that could contaminate surface water bodies. Basically, as weeds invade a thin turf, initially, the density of weeds and turf is adequate to cover the soil. Annual weeds, such as crabgrass, die off in the fall and leave bare soil exposed to the spring rains, allowing runoff to occur. It is these scenarios where weed control can be justified to preserve surface water quality.

Decreased turf density resulting from insect and disease damage, excessive traffic, poor drainage, etc. will allow weeds from weed seeds stored in the soil (soil seedbank) to germinate. A primary weed arising from seed in turf stands is the annual grass weed, crabgrass (*Digitaria* spp.).

7.3.1 Crabgrass Management

Among the 60 species in the genus *Digitaria*, 13 weedy species infest crops in the US. Of these 13, there are three major crabgrass species distributed in the United States: large, smooth, and southern. Smooth crabgrass is prominent in the northern climates, especially the north eastern US. Large crabgrass is found throughout the US. Southern crabgrass is primarily found in Florida and mid-southern states.

Crabgrass management has evolved over the last 60 to 70 years. Previously, the preferred management method was to alter the growing environment to limit crabgrass. Typically, this was achieved by drastically lowering the soil pH. The principle of pH manipulation was to alter the environment so that the organism (crabgrass) could not be successful. Unfortunately, the turf usually suffered as well.

Today, we rely on selective herbicides applied prior to crabgrass germination (preemergence) or after crabgrass emergence (postemergence). Again, concern over pesticide use has increased the need for understanding turfgrass and crabgrass ecology, innovative herbicide application programs that minimize exposure, and use of fertilizers and organic-based approaches.

7.3.2 Crabgrass Ecology

In spite of the available technology for managing crabgrass, it remains one of the most troublesome weeds in the US. Fidanza and Dernoeden (1996) have provided some useful information regarding crabgrass emergence patterns as influenced by growing degree days. In addition, studies from the 1950s and 1970s suggest that crabgrass could have up to a four-month period where seeds could continually emerge from the top 2” of soil. Of course, most managers are familiar with phenological indicators (such as forsythia and lilac flowering) as a tool to predict timing of emergence. Still, many ecological questions remain unanswered.

To more thoroughly understand the distribution and adaptation of crabgrass to regions and cropping systems, several weed science specialists in the US were surveyed on their view of crabgrass distribution. Approximately 90% of the respondents indicated that the three major species (smooth, large, southern), are regional problems. Large crabgrass was the most prominent species in all cropping systems from orchards to forage crops to golf and other turf areas. Smooth crabgrass was identified as a more significant problem in turf than any other system. When asked what factors limit crabgrass distribution and adaptation, the respondents believed that temperature, light, and seedbank were the most important, with moisture, cultivation, and soil pH to be of lesser importance.

A few respondents (4%) indicated that within a crabgrass species, the plants looked very different. Some suspected these plants responded to different environmental factors. Does this mean that smooth crabgrass from Rhode Island looks different than smooth crabgrass from Long Island, NY or from State College, PA? The results of several field and growth chamber experiments at Cornell indicated that, in fact, plants of the same species from different areas in the same region look different. However, when evaluating characteristics important for crabgrass control programs (such as emergence date, growth rate, and flower initiation) there were no significant differences *between* smooth and large crabgrass and *within* each species. Simply put, while species may be different and the plant may look different, in general they respond similarly to environmental factors.

A difference between the crabgrass species in the above study worth noting regards flowering (seed production). The study found that smooth crabgrass plants germinating after mid-July did not produce seed. These late germinating plants serve only to deplete the seed bank, in that the plants contribute less to the seedbank than they withdraw. This observation has been noted in other field studies.

7.3.3 Physical Disturbance, Soil Temperature, and Crabgrass Invasion

To more thoroughly understand the influence of soil temperature and seedbank factors, a comprehensive field study was initiated to investigate various types of physical disturbance on crabgrass emergence, development, and seed production.

Two study sites were established on mature stands of tall fescue and Kentucky bluegrass with different histories of crabgrass infestation. At both sites, four openings were created (1 inch, 2 inches, 4 inches, and 8 inches). Each site also had an undisturbed area. Each opening was maintained throughout the season by weekly clipping the encroaching leaf blades. The study area was maintained at 2.5” clipping height with no supplemental fertilization. One site had the thatch layer removed on half the plots to investigate the influence on crabgrass invasion. (The thatch layer was measured to be 0.5” thick.) Soil temperatures were monitored in each opening and in the undisturbed turf at 1” and 2” depths.

As expected, the undisturbed turf had significantly less crabgrass plants than any of the openings but was not able to completely exclude the crabgrass seedlings. The thatch layer reduced the crabgrass emergence in the disturbed plots but not in the undisturbed plots. In general, the undisturbed turf had 10 to 25% of the seedlings as the disturbed turf. In fact, crabgrass emergence varied little among the openings greater than 2 inches suggesting that any disturbance will result in crabgrass infestation if a seedbank is available.

Timing of emergence (seedlings emergence date) was not different relative to the amount of disturbance, however, smooth crabgrass germinated 1 week earlier than large crabgrass in disturbed versus undisturbed turf. In fact, initial crabgrass emergence began when soil temperatures in the undisturbed turf were between 54°F and 58°F for 3 consecutive days at the 1-inch depth. This is within the range of temperatures reported by Fidanza and Dernoden. Interestingly, the length of emergence (number of weeks that new seedlings emerged) was greater in undisturbed turf than in disturbed turf. This was possibly related to soil temperature which was significantly moderated by turf cover.

From a weed management perspective, based on these studies the window for successful preemergence control of smooth crabgrass in a disturbed turf is earlier and narrower as compared to undisturbed turf. However, an undisturbed turf that may become disturbed will need sustained protection from crabgrass infestations. Yet, as previously observed, late germinating smooth crabgrass plants will not produce seed and while short term visual quality is reduced, long term seedbank management is enhanced.

7.3.4 Do Fertilizer or Organic-Based Approaches Work?

The growth curve of a cool-season grass is marked by two significant periods of top growth. These are periods when temperatures are cool and daylight is long. In fact, research has shown that cool season turfgrasses produce about 60% of the entire shoot growth for the season the first 6 weeks in the spring (roughly about 25% of the growing season). This marked increase in turf density at the time of crabgrass emergence might have some ability to reduce crabgrass infestations.

Former Cornell Team Members Hummel and Neal conducted a demonstration in seven locations throughout New York State comparing fertilizing to not fertilizing with or without preemergence herbicides. The results indicated that when turf quality was acceptable prior to treatments, the fertilized plots reduced crabgrass populations by an average of 84% over the unfertilized plots. However, where turf quality began poor, fertility alone provided only 31% control as compared to unfertilized plots.

Recently, the natural organic product corn gluten meal (CGM) has been demonstrated to show herbicidal activity. The specific compounds responsible for root inhibition of germinating seedlings are five dipeptides: glutaminyl-glutamine, glycinyl-alanine, alaninyl-glutamine, alaninyl-asparagine, and alaninyl-alanine. Researchers at Iowa State University showed high rates of germination suppression of common lawn weeds. Conflicting results of efficacy trials conducted by Cornell University and Oregon State University researchers show little or no weed suppressive abilities. Still, CGM is 10% nitrogen and when applied according to label directions, it supplies 2 lb. of actual N per 1000 square feet. The nitrogen applied at this time extends top growth at the expense of root growth. However, when the turf is thin, the spring nitrogen will increase density that might provide some weed control. Nitrogen from the CGM is not consistent with recommendations for a fall-based fertility program. Several studies have concluded that CGM was able to provide about 30 to 60% crabgrass control in the first year, with greater than 80% control reported in subsequent years. To overcome this reduced control in the first year, several researchers have suggested applying a preemergence herbicide at the low rate in conjunction with the CGM.

Cornell Turf Team Members Andy Senesac, Ph.D. (Suffolk County Extension Weed Scientist) and Frank Rossi (Cornell Department of Horticulture) began an experiment comparing the use of corn gluten meal (Weed-Z-Stop, With Out Weeds, Safe and Simple) at two rates (both with and without herbicide applications) to treatments using organic fertilizer and synthetic fertilizers. The study, initiated in 1997, is being conducted in Ithaca and in Riverhead, NY on thin turf stands with a history of crabgrass invasion.

Results from the studies have been consistent with regard to the level of crabgrass control achieved with the CGM. After two years of applications, season-long control with CGM does not exceed 60%. In addition, control from the CGM is not significantly different from the synthetic fertilizer applications or, in some cases, from the organic fertilizers. Both sites have demonstrated a substantial increase in turfgrass density in response to the nitrogen from the various sources that likely has an influence on crabgrass invasion. Interestingly, the CGM plus herbicide treatment has maintained above 90% crabgrass control, suggesting that this transitional program might be effective.

While CGM is the only preemergence organic herbicide available for turf, there are a multitude of organic postemergence herbicides available for use. As a warning, most of the herbicides are nonselective and will harm turfgrasses. The organic herbicides are certified primarily through a nonprofit institution known as the Organic Materials Review Institute (OMRI). The institute reviews the herbicide's active and inert ingredients under the USDA's National Organic Standards list. The efficacy of organic herbicides is largely unknown, as few independent and university researchers have been able to evaluate the products. Cornell researcher Andy Senesac evaluated three organic herbicides in 2012, and found greater broadleaf weed control in Burnout II compared to WeedZap and Greenmatch EX. In comparison to these herbicides, the propane weed torch (Weed Dragon Propane Torch Kit) provided strong weed control without the application of chemicals. A propane tank attaches to the weed torch device to deliver intense heat from a flame. The weeds and turf are scorched within seconds, resulting in cell rupture of the heated leaf and bud tissues. Depending on the growth form of the plant, the thermal weeding technique may either kill the plant or reduce the biomass of aboveground plant plants. Some perennials and woody plants are able to regrow shoot and stems, while many annuals are removed completely. Repeated thermal weeding of perennials and woody plants improves the level of control. The timing of thermal weeding is crucial, and it should be used when the plants are at their earliest stages of development.

7.3.5 Herbicide Restrictions on NYS School Grounds and Day Care Centers

In May 2010, New York State enacted Chapter 85 of the Laws of 2010 that restricts use of pesticides on playgrounds, playing fields, and turf on school grounds and day care centers across the state. All grounds facilities, contracted lawn care operators, and individual applicators of school grounds and day care centers are expected to adhere to the new state law. Chapter 85 is referred to as the Child Safe Playing Fields Law. Emergency applications of herbicides not allowed under Chapter 85 are determined by the school board (for public schools), the county health department DOH, state DOH in certain counties, or the State DOH's Bureau of Toxic Substance Assessment (for non-public schools and day care centers), and the DEC (for non-public schools and day care centers concerning environmental matters). Detailed information on guidance of allowable and restricted herbicides is located at http://www.dec.ny.gov/chemical/41822.html and in Section 7.7 of this chapter.

7.3.6 Preemergence Herbicides and Crabgrass Control

IPM and water quality perspective. The indiscriminate use of preemergence herbicides runs counter to a well-implemented IPM program. Clearly, by inhibiting the successful emergence of crabgrass plants, there is little information available on the population that might develop. As a result, there is limited ability to develop historical records that lead to reasonable aesthetic and functional thresholds, the cornerstone of an IPM program. Still, preemergence herbicides are widely used.

Most preemergence herbicides have a great attraction for soil particles (adsorption coefficient; K_{oc}). In addition, these herbicides tend to be largely insoluble. Therefore, it is rare (except on extremely sandy soils) that preemergence herbicides used for turf in the north are found in the groundwater. However, they can pose a risk for surface runoff with most of the active ingredients rated as medium to large potential for surface runoff by the Natural Resources Conservation Service. Still, environmental fate studies conducted by turfgrass researchers in the last decade have concluded that a dense turf will significantly reduce runoff loss to surface water. Why then, if the turf is dense, do we need to apply a preemergence herbicide each year, even if there is little risk to water quality?

How do preemergence herbicides work? Preemergence herbicides that reduce the emergence of weed seedlings primarily act by inhibiting cell division. Cell division is one of the first steps in plant growth, as one cell divides into two cells, and then both cells elongate. Following a preemergent herbicide application, the chemical must be activated by moisture in the soil. The herbicide then becomes active at the soil thatch interface where many weed seeds are present. As weed seeds germinate under optimal environmental conditions, a small seedling protrudes from the seed and begins to grow towards the soil surface. The seedling has enough energy stored in the seed to reach the surface, at which time it is then able to begin using light energy in photosynthesis. It is important to note that preemergence herbicides do not affect un-germinated (dormant) seeds. The seed must germinate to encounter the herbicide in the soil-thatch interface.

Once the seedling encounters the herbicide, cells in the seedling continue to expand, but not divide. This expansion (not growth) depletes the energy stored in the seed before the seedling can emerge and become “self-sufficient”. The result is that the plant does not survive. Over time, there is question as to how many years of preemergence herbicide applications are needed to reduce the crabgrass seedbank below the threshold level. Are preemergence herbicide applications needed every year to every area of turf, or just on areas where the turf is always thin (along paved surfaces)?

How long do preemergence herbicides work? The duration of herbicide activity (also called residual) depends on environmental conditions such as moisture, temperature, light, and the amount of organic matter in the soil. Once applied and activated, the herbicide remains at a critical concentration at the soil-thatch interface for periods ranging from 6 to 16 weeks, depending on the product.

Herbicide degradation also affects how long a preemergence herbicide lasts. Preemergence herbicides degrade through chemical or microbial processes in the soil until the concentration falls below the critical level where activity is reduced. This can be accelerated when the soil remains warm for extended periods of time. Warm, moist soils encourage microbial degradation of the herbicides carbon structure; the microbes use it as a food source. This is why in years of early and extended soil warming, preemergence herbicides fail to provide season-long control. Simply, the crabgrass germination period exceeds the residual activity of the herbicide.

Do preemergence herbicides affect turf growth? The effect of preemergence herbicides on rooting has been investigated during sod establishment where new roots must penetrate the preemergence herbicide barrier. Hummel found that annual applications of prodiamine applied at 2 lb. ai/A (4 times the high use rate) reduced rooting of established Kentucky bluegrass by about 8%. However, in general, preemergence herbicides are thought to be less injurious to root development in established turf.

Turfgrass ecology and physiology could explain this further. Grass root tips are regions of active cell division (called meristems). The root meristems could be affected if it contacts a preemergence herbicide that inhibits cell division. As mentioned previously, turfgrass rooting is most active in the early spring when the soil is cool and top growth has yet to be initiated. It follows, then, that a preemergence herbicide which inhibits cell-division could affect root production during a critical development stage. Accordingly, delaying a preemergence application until soil temperatures warm and roots are through their active stage would avoid the herbicide injuring the new roots. Yet, if crabgrass has already emerged, most preemergence products will not provide control, hence, proper timing remains critical.

For many years, turfgrass pathologists have speculated that the use of preemergence herbicides can contribute to reduced disease tolerance. There are several anecdotal reports of increased bluegrass susceptibility to leafspot, but few documented studies. Researchers at Clemson University identified several preemergence herbicides that can increase the incidence of brown patch on tall fescue; however, the class of herbicides investigated is not widely used on cool-season turf. In addition, Hummel found an increase in severity of Necrotic ringspot with prodiamine applied above the labeled rates. Still, preemergence herbicide influence on cell division may have physiological side effects that are not well understood.

Core cultivation and preemergence herbicide activity. The role of physical disturbance on crabgrass emergence and development has been discussed. However, many questions have been asked regarding the influence of core cultivation on preemergence herbicide performance. One might think that by disrupting the herbicide barrier, crabgrass control would be reduced. However, in two separate studies where preemergence herbicides were applied and then the area core cultivated, no reduction in crabgrass control was observed. This was true even if the cores were processed or removed.

Preemergence herbicides applied in the fall. In an effort to reduce the amount of activity required on a turf stand in the spring; many managers have experimented with preemergence herbicide applications in the fall or late season. Researchers over the years have concluded that the effectiveness of this practice is highly product, rate, and environmentally related. Bhowmik at the University of Massachusetts found that prodiamine (*Barricade) applied at 0.5 lb. ai/A in October 1997 provided 65% control when rated in August 1998. In fact, this was not significantly different from the April 1998 application of prodiamine at 0.65 lb. ai/A. The best prodiamine program (92% control) was 0.65 lb ai/A applied in October, followed by 0.38 lb. ai/A applied in April. Comparatively, in 1998, dithiopyr (*Dimension) applied at rates of 0.25 to 0.38 lb. ai/A did not provide even 80% control, regardless of application strategy. These results confirm previous reports that the dinitroaniline family of herbicides (pendimethalin, prodiamine, trifluralin+benefin) can provide season long control when applied in the previous fall, while materials such as bensulide, dithiopyr, oxadiazon (*NYRonstar) and siduron (Tupersan) are not as effective.

A significant limitation to the use of preemergence herbicides in the fall is the potential to restrict overseeding or other turf establishment procedures the following spring. As discussed earlier, the effect of the herbicides on cell division is rarely selective in that all germinating grass seeds can be inhibited (except in the case of siduron, which is selective for warm season grass seed and can be used at the time of turf establishment). Consequently, if there is turf loss over the winter, the ability to recover the area from seed might be affected.

Researchers at Penn State University applied several preemergence herbicides in October and then overseeded the areas with creeping bentgrass (CB), Kentucky bluegrass (KBG) or perennial ryegrass (PR) in the spring. The plots were rated for density in June. All preemergence herbicides delayed seed germination and seedling development of all grass species. Overall, PR seedings were the most successful in establishing on oxadiazon and dithiopyr treated plots. Of the three species tested, bentgrass was the most sensitive to herbicide residual with no plot reaching 50% density by June.

Clearly, the fall strategy has a trade-off in that dithiopyr and oxadiazon will allow turf establishment in the spring following preemergence herbicide application in the fall but they do not provide acceptable season-long crabgrass control. In contrast, the dinitroaniline materials provide acceptable season-long control but severely limit the success of spring seedings.

7.3.7 Postemergence Crabgrass Control

Crabgrass growth and development. Studies have indicated that crabgrass plants in more highly disturbed turf with low density reach a size more difficult to manage (greater than two tillers) more rapidly. In contrast, the plants that emerge in undisturbed turf need almost 7 weeks to reach the two tiller size. This would permit the turf manager to observe crabgrass pressure following germination then determine the appropriate postemergence strategy over a longer period.

When reviewing the ecological aspects of summer annual weed infestations exclusively from seed, an annual measure of contributions to the seedbank is vital. Undisturbed turf reduces crabgrass seed production in the surviving plants as compared to disturbed turf. For example, slightly disturbed turf produces 5 times the amount of seed as undisturbed turf. Undisturbed turf is a significant long term management strategy. If crabgrass thresholds could be increased as part of an IPM program, there would be a net depletion of the seedbank in dense turf stands.

IPM approach. Monitoring weed populations is not widely practiced in the turfgrass industry mostly because adequate turfgrass density restricts weed invasion and also due to the widespread use of preemergence herbicides. Additionally, aesthetic thresholds on high value turf areas and functional thresholds on golf putting greens and sports fields are essentially zero; by the time crabgrass is visible it has exceeded threshold levels or it might be too large to effectively control. Therefore, crabgrass skeletons left over from the previous fall, will provide insight into where infestations might occur or, as mentioned previously, areas where turf is consistently thin could be more closely monitored for crabgrass infiltration.

The time required for the level of monitoring needed to successfully reduce pesticide use may be prohibitive to traditional lawn care companies that visit a site 4 to 5 times per year. However, golf course superintendents and sports field and grounds managers who are at the site each day could implement a population-based approach by monitoring at appropriate times.

Postemergence herbicides. Effective control of emerged crabgrass plants is highly dependent on growth stage and environmental conditions, independent of the herbicide used.

MSMA is no longer available for crabgrass control. The EPA canceled registrations of MSMA for turfgrass management over concerns that organic arsenic could convert into the toxic, inorganic form of arsenic. Although MSMA was effective in controlling crabgrasses and goosegrass, herbicides containing quinclorac were recently approved for registration. Quinclorac is now available for restricted use (spot treatment only or not allowed for use in Long Island) in many products. Herbicides containing quinclorac have shown decent control of many lawn weeds, including crabgrass.

Fenoxaprop (Acclaim Extra) is effective on crabgrass plants from emergence to the 3 tiller stage. Larger plants may need several applications and it may take 14 to 21 days before the crabgrass is eliminated. Additionally, the effectiveness of fenoxaprop is reduced when plants are drought stressed. Research has indicated that moisture stress must be alleviated within 48 hours of applying fenoxaprop for effective control.

7.3.8 An Integrated Approach to Crabgrass Control.

The successful implementation of IPM programs based on reasonable thresholds poses a unique challenge for turf managers, lawn care providers, and sod producers. The widespread use of preemergence herbicides in most instances ensures a weed-free turf, regardless of whether or not the herbicide application is needed to provide a weed-free turf.

While herbicide use has environmental concerns, research indicates that, when used properly, applications do not pose water quality concerns and have low environmental toxicity. However, a more integrated approach that sets reasonable thresholds, utilizes ecological information as a base for management decisions, monitors weed populations, and implements effective control strategies is likely to reduce pesticide use.

The first and foremost strategy is to maintain turfgrass density. If the turf is thin, implement a spring based fertilizer program or begin applying CGM. Additionally, introduce rapidly germinating turfgrass species (such as ryegrass) to compete with crabgrass seedlings for resources. Improved density alone in the first year can provide 30 to 80% control, depending on how thin the turf was to start. In areas where crabgrass infestation is likely, particularly along paved surfaces, a preemergence strategy might be warranted where competition from turf might be reduced. However, one could argue that crabgrass and other annual weeds invade these areas and stabilize the soil; a key aspect of urban water quality. Nevertheless, the visual quality expectations of most turf areas will not allow this level of infestation.

An integrated approach would be to observe the emergent weed population then use a timely postemergence herbicide to control existing plants in combination with a preemergence herbicide to prevent further infestation. This strategy will reduce the effect preemergence herbicides have on turfgrass rooting (which will have slowed in response to the herbicide application) and reduce the amount of preemergence herbicide applied by targeting areas known to be infested. However, if fall seeding is planned, consider using a preemergence herbicide with a shorter residual to reduce the influence on turf seedling development.

Managing annual weeds, such as crabgrass, that infest exclusively from the seedbank can be challenging on highly disturbed turf areas. Annual weeds provide an opportunity to utilize ecological information to the advantage of the turf. Turf density reduces crabgrass infestations, however, not always below threshold levels. If turf density can be maintained until emerged weed seedlings are not able to produce viable seed, the seedbank will be depleted. This will require adjustments in weed threshold levels. Furthermore, the impact of the annual use of preemergence herbicides on the crabgrass seedbank must be better understood to justify continuing this practice. A crabgrass management program must be viewed in the larger context of environmental quality and realistic expectations of turfgrass quality. As such, society will more completely understand the role of a well-maintained turf in an urban environment and demand a more integrated approach.

Table 7.3.1 – Pesticides labeled for treatment of Annual bluegrass

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
benefin (Lebanon Balan 2.5G)	1.38 lbs/1000 sq ft PRE	-	3	26	Not for use on sod farms or turf being grown for commercial seed.
*NYbensulide (Bensumec 4LF)	9.4 fl oz/1000 sq ft PRE	Until Dry	8	318	For use only on golf courses (greens, tees and bentgrass fairways only) and on residential lawns. Do not use on parks, recreational areas, or other public sites.
bispyribac-sodium (Velocity SG)	1-6 oz/acre POST	12	2	0 - 1	Do not apply to golf greens or roughs. For use only on bentgrass, tall fescue, and permanently established perennial ryegrass.
*NYdithiopyr (Dimension Ultra 40WP)	0.47-0.625 lb/acre PRE	12	3	3 - 4	Do not apply to golf course putting greens. Do not apply within 3 months of harvesting sod.
*NYethofumesate (Prograss)	1.5 fl oz/1000 sq ft PRE/EPO	12	8	21	
mesotrione (Tenacity)	5-8 fl oz/acre PRE	12	27	2 - 4	Do not use on golf course putting greens and maintain a five-foot buffer between treated areas and putting greens. Annual bluegrass suppression only.
*NYoxadiazon (Ronstar G)	2.25 - 4.5 lbs/1000 sq ft PRE	12	14	88 - 175	Do not apply to putting greens or tees. Not for use on residential properties.
pendimethalin (Pendulum)	1.3-1.8 oz/1000 sq ft PRE	24	3	40 - 55	
pendimethalin (Halts)	2 lbs/1000 sq ft PRE	-	3	45	
*NYpendimethalin (Corral 2.86G)	57-75 lb/acre depending on grass species PRE	24	3	46 - 61	
pendimethalin (Pendulum Aquacap)	1.1-1.6 fl oz/1000 sq ft PRE	24	3	36 - 53	
pendimethalin (Pendulum 2G)	75-100 lb/acre PRE	24	3	45 - 60	
pendimethalin (Lesco Pre-M)	1.3-1.8 fl oz/1000 sq ft PRE	24	3	42 - 58	Do not use on greens or injury may occur.
*NYprimisulfuron-methyl (Beacon)	0.76 oz/acre POST	12	2	1	Special Local Need No NY-080015. For weed control in established stands of Kentucky bluegrass grown for sod. User must sign an indemnification available online from Syngenta prior to use.
*NYprodiamine (Barricade 65 WG)	0.36-0.83 oz/1000 sq ft; rate depends on turfgrass species PRE	12	-	7 - 17	Do not apply to golf course putting greens. Do not harvest sod until 90 days after application.

prodiamine (Barricade 4 FL)	0.23-0.70 oz/1000 sq ft; rate depends on turfgrass species PRE	12	-	3 - 9	Not for use on golf course putting greens. Do not harvest sod until 90 days after application.
trifluralin (Lebanon Treflan 5G)	1.8 lbs/1000 sq ft PRE	-	3	74	Not for use on sod farms or turf being grown for commercial seed.
trifluralin, benefin (Lebanon Proscape Fertilizer with Team Pro .86% Preemergent Weed Control)	4-8 lbs/1000 sq ft PRE	-	3 + 3	27 - 54	Do not apply to golf course putting greens.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 7.3.2 - Pesticides labeled for treatment of Bentgrasses

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
mesotrione (Tenacity)	4-5 fl oz/acre POST	12	27	2 - 2	Do not use on golf course putting greens and maintain a five foot buffer between treated areas and putting greens.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.3 – Pesticides labeled for treatment of Crabgrass, goose grass and other annual grassy weeds

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
benefin (Lebanon Balan 2.5G)	1.38 lbs/1000 sq ft PRE	-	3	26	Not for use on sod farms or turf being grown for commercial seed.
*NYbensulide (Bensumec 4LF)	5.6-7.3 fl oz/1000 sq ft PRE	Until Dry	8	190 - 247	For use only on golf courses (greens, tees and bentgrass fairways only) and on residential lawns. Do not use on parks, recreational areas, or other public sites.
*NYdithiopyr (Dimension Ultra 40WP)	0.47-0.625 lb/acre PRE	12	3	3 - 4	Do not apply to golf course putting greens. Product can provide "early postemergence" control of crabgrass during the early stages of crabgrass growth after the crabgrass has emerged from the ground. Do not apply within 3 months of harvesting sod.

Table 7.3.3 – Pesticides labeled for treatment of Crabgrass, goose grass and other annual grassy weeds

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY ethofumesate (Prograss)	1.5 fl oz/1000 sq ft PRE/EPO	12	8	21	Not effective on goosegrass.
fenoxaprop ethyl (Acclaim Extra)	0.3-0.9 fl oz/1000 sq ft POST	24	1	2 - 7	
mesotrione (Tenacity)	5-8 fl oz/acre PRE/POST	12	27	2 - 4	Do not use on golf course putting greens and maintain a five-foot buffer between treated areas and putting greens. For best postemergence control, apply to less than 4 tiller crabgrass and goosegrass.
*NY oxadiazon (Ronstar G)	2.25 - 4.5 lbs/1000 sq ft PRE	12	14	88 - 175	Do not apply to putting greens or tees. Not for use on residential properties.
pendimethalin (Pendulum)	1.3-2.6 oz/1000 sq ft PRE	24	3	40 - 80	
pendimethalin (Halts)	2 lbs/1000 sq ft PRE	-	3	45	
*NY pendimethalin (Corral 2.86G)	57-75 lb/acre depending on grass species PRE	24	3	46 - 61	
pendimethalin (Pendulum Aquacap)	1.1-2.3 fl oz/1000 sq ft PRE	24	3	36 - 76	
pendimethalin (Pendulum 2G)	75-100 lb/acre PRE	24	3	45 - 60	
pendimethalin (Lesco Pre-M)	1.3-2.6 fl oz/1000 sq ft PRE	24	3	42 - 83	Do not use on greens or injury may occur.
*NY prodiamine (Barricade 65 WG)	0.36-0.83 oz/1000 sq ft; rate depends on turfgrass species PRE	12	-	7 - 17	Do not apply to golf course putting greens. Do not harvest sod until 90 days after application.
prodiamine (Barricade 4 FL)	0.23-0.70 oz/1000 sq ft; rate depends on turfgrass species PRE	12	-	3 - 9	Not for use on golf course putting greens. Do not harvest sod until 90 days after application.
siduron (Lebanon Crabgrass Control 4.6% Tupersan)	4 lbs/1000 sq ft PRE	-	7	94	Not for use on sod farms or turf being grown for commercial seed.
siduron (Tupersan)	1 1/2- 4 1/2 oz/1000 sq ft PRE	4	7	8 - 8	Not effective on goosegrass. Use at seeding or on fall plantings.
topramezone (Pylex)	0.023-0.034 fl oz/1000 sq ft POST	12	-	1 - 1	Do not apply to golf course collars or greens. Maintain a 5-ft buffer between treated areas and bentgrass greens. COC or MSO spray additive is required.

Table 7.3.3 – Pesticides labeled for treatment of Crabgrass, goose grass and other annual grassy weeds

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
trifluralin (Lebanon Treflan 5G)	1.8 lbs/1000 sq ft PRE	-	3	74	Not for use on sod farms or turf being grown for commercial seed.
trifluralin, benefin (Lebanon Proscape Fertilizer with Team Pro .86% Preemergent Weed Control)	4-8 lbs/1000 sq ft PRE	-	3 + 3	27 - 54	Do not apply to golf course putting greens.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.

Table 7.3.4 – Pesticides labeled for treatment of Nimblewill

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
mesotrione (Tenacity)	4-5 fl oz/acre POST	12	27	2 - 2	Do not use on golf course putting greens and maintain a five foot buffer between treated areas and putting greens.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.5 – Pesticides labeled for treatment of Perennial grassy weeds (quackgrass, tall fescue, orchardgrass, bentgrass, etc.)

Active ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
glyphosate (Razor Pro)	1-2 qt/acre NSPOST	4	9	13 - 26	

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.6 – Pesticides labeled for treatment of Poa trivialis

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
bispyribac-sodium (Velocity SG)	1-6 oz/acre POST	12	2	0 - 1	Do not apply to golf greens or roughs. For use only on bentgrass, tall fescue, and permanently established perennial ryegrass.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.7 – Pesticides labeled for treatment of Tall fescue and perennial ryegrass

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
chlorsulfuron (Alligare)	.25 - .5 oz/acre	4	2	0 - 1	For use on non-crop industrial sites.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.8 – Pesticides labeled for treatment of Wild onion, garlic

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
chlorsulfuron (Alligare)	1-3 oz/acre	4	2	1 - 4	For use on non-crop industrial sites.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.9 – Pesticides labeled for treatment of Yellow nutsedge

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
bentazon (Basagran T & O)	0.55-0.75 fl oz/1000 sq ft POST	48	6	13 - 17	Thorough spray coverage of yellow nutsedge is essential for maximum control. Not for use on golf greens or collars.
halosulfuron-methyl (Sedgehammer)	.66 - 1.33 oz/acre POST	12	2	1 - 1	Do not apply to golf course putting greens.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.3.10. Efficacy and persistence of registered preemergence herbicides in NY[1].

Common name	Crabgrass Control (4-6 weeks)	Crabgrass Control (12-15 weeks)	Annual bluegrass control	Broadleaf control	Injury/Safety
bensulide	E	G	E	F	Safe on annual bluegrass and bentgrass putting greens
oxadiazon	E	E	G	E	Injures annual bluegrass, bentgrass and red fescue
bensulide plus oxadiazon	E	E	G	E	Safe on bentgrass fairways
siduron	F	P	P	F	Safe at time of establishment
dithiopyr	E	E	G	G	Safe on bentgrass. Pre and Early post activity. Restrictions on use on LI
pendimethalin	E	E	G	E	Injures close mown bentgrass and annual bluegrass
benefin	E	F	G	P	Injures close mown bentgrass and annual bluegrass
trifluralin	E	F	F	P	Injures close mown bentgrass and annual bluegrass
benefin plus trifluralin	E	G	F	P	Injures close mown bentgrass and annual bluegrass
prodiamine	E	E	G	E	Injures close mown bentgrass and annual bluegrass

[1] E= excellent (>85% control), G=good (75-85% control), F=fair (65-75% control), P=poor (<65% control)

7.3.9 Perennial Grassy Weed Control

Poa trivialis (Roughstalk bluegrass) is a perennial grass that spreads by stolons forming light green patches in the turf. It is best adapted to shady, moist, or over-watered sites. Because of this, it often appears in mixtures with Kentucky bluegrass and perennial ryegrass recommended for shady areas.

Two theories persist about how *Poa trivialis* is introduced to a turf stand. Some believe that *Poa trivialis* grows naturally over most of the world and *Poa trivialis* seeds or stolons can germinate after lying dormant for many years, thus contaminating a turf stand. Most believe that it was introduced as a contaminant in turf seed and seed producers have since self-imposed *Poa trivialis* growing and shipping restrictions to help prevent this. Nonselective control of roughstalk bluegrass may not be practical on fairways, tees, sports fields, or home lawns. Sulfosulfuron (Certainty) was used for controlling *Poa trivialis*, but has recently received a label change. Certainty can no longer be used on cool season turfgrass fields. The label indicates the herbicide can still be applied to warm season turf.

Bentgrass Removal from Bluegrass and Ryegrass Areas: Mesotrione, the active ingredient in Syngenta's Tenacity, has been found to provide selective control of creeping bentgrass in Kentucky bluegrass turf. A majority of field trials have concluded that fall applications provide the most complete control and two applications at three week intervals is most effective. Of course once the patches of bentgrass are controlled it will display a "bleached white" appearance due to the mode of action of Tenacity. Additionally, the area will require overseeding to fill in bare areas and Tenacity offers the ability to be used at time of seeding. Therefore, this new herbicide will provide excellent bentgrass control and allow for recovery using overseeding.

7.4 Cultural Control of Broadleaf Weeds

Broadleaf weed populations in turfgrass are influenced by cultural practices. For example, low mowing and inadequate nitrogen favor white clover. Low mowing also weakens turf and favors weeds such as carpetweed, spurge, plantains, and dandelion. Poorly drained areas can favor weeds such as ground ivy, while compacted sites favor knotweed and plantains.

Proper management practices to maintain a dense, vigorous turf is the best and most lasting method for broadleaf weed control. Of particular importance are proper fertilization, mowing, and watering. Several broadleaf weed species cannot be satisfactorily controlled with herbicides, further increasing the importance of proper cultural management to reduce their establishment and spread**.** Herbicides should be considered an aid, but not a cure, for broadleaf weed problems in landscaped turf.

7.5 Chemical Control of Broadleaf Weeds

Broadleaf weeds may require herbicide treatment for their removal so that the turf can be improved through better management and cultural practices. Many broadleaf-specific postemergence herbicides are available but the diversity of weed species results in varying responses to the herbicide.

Proper weed identification is the first step to ensuring success with herbicides. The definitive resource for weed identification is "Weeds of the Northeast" by Richard H. Uva, Joseph C. Neal, and Joseph M. DiTomaso. This publication is available through Cornell University Press (phone: 607-277-2211 or www.cornellpress.cornell.edu).

Table 7.5.1 Specific use restrictions for dithiopyr in New York State[1].

	Maximum use rate in NY		Labeled for use		Allowable use	
Product	***By active ingredient***	***By product***	***In New York State***	***On Long Island***	***Turf***	***Landscape***
*Dimension 2EW	0.5 lb per acre per year	2 pints per acre per year	Commercial applicators only	1 pint per acre (0.25 lb active ingredient)	Y	Y
*†Dimension EC	0.5 lb per acre per year	2 quarts per acre per year	Commercial applicators only	Not for use in Nassau and Suffolk Counties	Y	Y
*[NY]Dimension Ultra 40WP	0.25 lb per acre per year	10 ounces per acre per year	Commercial applicators only	Allowable for use	Y	Y
*†Dimension 0.10 & 0.15G (Professional with fertilizer)	0.5 lb per acre per year	330 and 500 pounds per acre per year depending on formulation	Commercial applicators only	Not for use in Nassau and Suffolk Counties	Y	N
Dithiopyr G (Professional and consumer/retail) Various products and manufacturers	Proprietary products containing dithiopyr and fertilizer available for use in New York State and on LI. Professional products restrict maximum use to 0.25 lb active ingredient per acre per year on Long Island. (Unless professional products restrict maximum use to 0.25 lb active ingredient per acre per year, they are not allowed for use on LI.) Check labels for other restrictions.					

[1] Compiled by Andrew Senesac, Extension Weed Specialist, Cornell Cooperative Extension – Suffolk County
* Restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
† Not for use in Nassau and Suffolk Counties
Δ Rate and/or other application restrictions apply in New York State. See label for more information.

As a result of the variety of broadleaf weed species found in turf, most products have two or more different active ingredients and are sold as prepackaged mixtures. Because several manufacturers sell broadleaf herbicide combinations often under different trade names that differ in formulation and concentration, it is vital that you follow the label directions. Applying rates too low may result in inadequate control, while applying rates too high may cause turfgrass injury.

7.5.1 Herbicide Mixtures

The use of prepackaged, combination herbicide mixtures is very common. Combination products control a broader range of weeds than single herbicides. Some herbicide mixtures may effectively control certain weeds that cannot be easily controlled by the individual herbicides used alone. Some commonly used herbicide mixtures are found in Table 7.5.2. These herbicides will successfully control many broadleaf weeds found in cool season turf.

Some issues have arisen with clopyralid and products containing clopyralid (such as *[NY]†Confront and *[NY]†Millennium) due to their persistence in mulches and manures. Because of this problem, clopyralid is no longer available for use in residential lawns. After the herbicide is applied to lawns or pastures, it ends up in clippings or in animal manure that may be further composted. Due to the persistence of the herbicide, it does not break down as rapidly in the composting process as expected. The herbicide can remain active in the compost for up to 18 months, leading to unexpected toxicity when compost is applied to ornamentals or garden plants. This problem has been observed in Washington, California, and a few other states where municipal compost is applied to gardens. Due to these concerns, fluroxypyr appears to be an effective replacement for clopyralid in turf and ornamentals.

Several new sulfonylurea herbicides have been approved for use in NY over the last few years. Products include chlorsulfuron to add to the previously labeled halosulfuron used for nutsedge control. These herbicides have extremely low toxicity to animals but are highly toxic to susceptible weeds at very low rates. They are labeled on many warm and cool season turfgrasses, including Kentucky bluegrass. These products control establishment of wild garlic, onions, ryegrass, tall fescue and other undesirable grasses as well as numerous broadleaf weeds. Due to these products having a very specific mode of action, repeated applications can lead to resistant weeds.

Several new herbicide combinations are now available that contain carfentrazone. Carfentrazone increases the speed of visual symptoms, with results often seen within hours after application. Carfentrazone containing products enhance the activity spectrum for broadleaf weed management and excel in cool weather broadleaf control. Applications can be made in early spring and the products are rainfast in as little as 3 hours after application.

Fiesta is a new reduced risk herbicide from Neudorff made of iron HEDTA. Fiesta can be applied in broadcast form using any hand-held or backpack sprayer. A dilute version of the iron HEDTA herbicide can be purchased for home lawn and garden use as a spot application (Ortho Elementals Lawn Weed Killer). The active ingredient in the products is comprised of iron that is chelated with hydroxyethylenediaminetriacetic acid (HEDTA) to form FeHEDTA. At high levels, iron HEDTA is toxic to broadleaf plants, resulting in oxidative damage at the cellular level, tissue necrosis, and die off. Little injury occurs for most turfgrasses. However, Fiesta should not be applied to bentgrasses. For most grasses, foliar spraying of ion HEDTA results in a temporary darkening of the contacted tissue (deep green). Subsequent shoot growth and mowing removes the discoloration.

7.5.2 Using Broadleaf Herbicides

In general, the best times of year to control most broadleaf weeds are fall (especially late September) or spring (especially May). To use these herbicides effectively for broadleaf weed control in turf, it is critical to read and follow all label directions. Apply products when the temperature is above 70°F and the weeds are actively growing. Do not apply when the temperature is over 85°F because turfgrass injury may result and some of these products (i.e., low volatile esters) are prone to volatilization causing injury to nearby ornamental plants. Most products are absorbed through the leaves so it is best not to mow one day prior to and after spraying. Liquid spray formulations are generally more effective than granular formulations of broadleaf herbicides; granular formulations typically only provide 30 to 40 percent control. When using granular formulations, be sure leaves are moist.

There are several precautions one should follow when using broadleaf herbicides:

- Most ornamental plants, trees, shrubs, and vegetables are susceptible to injury from these herbicides.
- Avoid applying on windy days as even a slight breeze can transport spray droplets to susceptible ornamental and garden plants.
- Ester formulations are more likely to injure nearby ornamentals and vegetables when sprayed at high temperatures.
- If using products containing dicamba, you should be aware that it is mobile in soils and can be absorbed by plant roots. Products containing dicamba should not be used near the drip-line of trees or near ornamentals where it can be absorbed by roots.
- Avoid herbicide use on newly-seeded turf. Wait until the new lawn has been mowed at least three times before treating (usually about 6 to 8 weeks after seedling emergence).

Most broadleaf herbicides are safe for use on established tall fescue, Kentucky bluegrass, perennial ryegrass, and fine-leaf fescues (i.e., strong creeping red, hard, Chewings, blue and sheep). However, some restrictions apply when using them on creeping bentgrass. Broadleaf herbicides also have the potential to cause some yellowing. Consult the product label for specific grass species concerns.

Table 7.5.1 – Pesticides labeled for treatment of Annual broadleaf weeds (e.g. chickweeds, henbit, knotweed, oxalis, spurge, annual speedwell

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
2,4-D dimethylamine salt, MCPP, dicamba (Weed Beater)	4 fl oz/1000 sq ft POST	-	4 + 4 + 4	23	Not for use on sod farms or turf being grown for commercial seed.
*NY†2,4-D, dimethylamine salt, MCPP, dicamba, sulfentrazone (Surge)	1.25-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4 + 14	21 - 25	Only one application per year of this product is allowed in New York state.
*NY†clopyralid, 2, 4-D, triisopropanolamine salt, triclopyr (Riverdale XRM-5202)	1.1-1.5 oz/1000 sq ft POST	48	4 + - + 4	2 - 3	Do not use on golf course greens or tees.
dicamba, MCPA, triclopyr (Cool Power)	0.91-1.29 fl oz/1000 sq ft POST	-	4 + 4 + 4	57 - 81	Not for use in sod farms, or in seed production.
*NYdithiopyr (Dimension Ultra 40WP)	0.47-0.625 lb/acre PRE	12	3	3 - 4	Do not apply to golf course putting greens. Do not apply within 3 months of harvesting sod.
MCPP, dicamba, carfentrazone, MCPA (Power Zone)	1.3-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + 4	63 - 87	
mesotrione (Tenacity)	5-8 fl oz/acre PRE	12	27	2 - 4	Do not use on golf course putting greens and maintain a five foot buffer between treated areas and putting greens.
pendimethalin (Pendulum 2G)	75-100 lb/acre PRE	24	3	45 - 60	Do not exceed a maximum rate of 100 lbs/acre/application for use on residential turfgrass (turf in any residential situation as well as schools, parks and playgrounds.
pendimethalin (Halts)	2 lbs/1000 sq ft PRE	-	3	45	
*NYpendimethalin (Corral 2.86G)	57-75 lb/acre depending on grass species PRE	24	3	46 - 61	
pendimethalin (Pendulum Aquacap)	1.1-1.6 fl oz/1000 sq ft PRE	24	3	36 - 53	
pendimethalin (Pendulum)	1.3-1.8 oz/1000 sq ft PRE	24	3	40 - 55	

pendimethalin (Lesco Pre-M)	1.3-1.8 fl oz/1000 sq ft PRE	24	3	42 - 58	Do not use on greens or injury may occur.
*NY prodiamine (Barricade 65 WG)	0.36-0.83 oz/1000 sq ft; rate depends on turfgrass species PRE	12	-	7 - 17	Do not apply to golf course putting greens. Do not harvest sod until 90 days after application.
prodiamine (Barricade 4 FL)	0.23-0.70 oz/1000 sq ft; rate depends on turfgrass species PRE	12	-	3 - 9	Not for use on golf course putting greens. Do not harvest sod until 90 days after application.
topramezone (Pylex)	0.023-0.034 fl oz/1000 sq ft POST	12	-	1 - 1	Do not apply to golf course collars or greens. Maintain a 5-ft buffer between treated areas and bentgrass greens. COC or MSO spray additive is required.
trifluralin, benefin (Lebanon Proscape Fertilizer with Team Pro .86% Preemergent Weed Control)	4-8 lbs/1000 sq ft PRE	-	3 + 3	27 - 54	Do not apply to golf course putting greens.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.

† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 7.5.2 – Pesticides labeled for treatment of Chickweed

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY †2, 4-D, triisopropanolamine salt, fluroxypyr, triclopyr (Momentum FX2)	1.1-1.5 fl oz/1000 sq ft POST	48	- + 4 + 4	6 - 8	Do not use on golf course greens or tees.
*NY †2,4-D dimethylamine salt, dicamba, fluroxypyr (Escalade 2)	0.75-1.1 fl oz/1000 sq ft POST	48	4 + 4 + 4	24 - 36	
2,4-D dimethylamine salt, MCPP, dicamba (Weed Beater)	4 fl oz/1000 sq ft POST	-	4 + 4 + 4	23	Not for use on sod farms or turf being grown for commercial seed.
2,4-D dimethylamine salt, MCPP, dicamba (Gordon's Trimec Ready to Spray Lawn Weed Killer)	6.4 fl oz/1000 sq ft POST	-	4 + 4 + 4	28	See label for specific setback distance restrictions from water bodies.

Table 7.5.2 – Pesticides labeled for treatment of Chickweed

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY†2,4-D, dimethylamine salt, dicamba, clopyralid (Millennium Ultra 2)	0.73-1.1 fl oz/1000 sq ft POST	48	4 + 4 + 4	19 - 29	Not for use on bentgrass greens and tees. Not for use on residential turf.
*NY†2,4-D, dimethylamine salt, MCPP, dicamba, sulfentrazone (Surge)	1.25-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4 + 14	21 - 25	Only one application per year of this product is allowed in New York state.
2,4-D, dimethylamine salt, triclopyr (Chaser 2 Amine)	1 fl oz/1000 sq ft POST	48	4 + 4	25	
*NY2,4-D, dimethylamine salt, triclopyr (Turflon II Amine)	1 fl oz/1000 sq ft POST	48	4 + 4	25	
2,4-dichlorophenoxyacetic acid, dicamba, penoxsulam (Lesco Lockup Extra 2 with Fertilizer)	3.4-4 lbs/1000 sq ft POST	48	4 + 4 + 2	29 - 34	
Δ2,4-dichlorophenoxyacetic acid, MCPP, dicamba (Strike 3)	0.67-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4	13 - 30	
*NY†clopyralid, 2, 4-D, triisopropanolamine salt, triclopyr (Riverdale XRM-5202)	1.1-1.5 oz/1000 sq ft POST	48	4 + - + 4	2 - 3	Do not use on golf course greens or tees.
*NY†clopyralid, triclopyr (Confront)	0.55 fl oz/1000 sq ft POST	48	4 + 4	9	Do not apply to putting greens or tees. In New York State, restricted to golf course use only.
dicamba, MCPA, triclopyr (Cool Power)	0.91-1.29 fl oz/1000 sq ft POST	-	4 + 4 + 4	57 - 81	Not for use in sod farms, or in seed production.
MCPP, dicamba, 2, 4-D, triisopropanolamine salt (Trupower 3 Selective)	0.67-1.5 fl oz/1000 sq ft POST	48	4 + 4 + -	4 - 9	
MCPP, dicamba, carfentrazone, 2,4-D, 2-ethylhexyl ester (Speed Zone)	1.1-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + -	18 - 30	Do not apply to bentgrass greens.

Table 7.5.2 – Pesticides labeled for treatment of Chickweed

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
MCPP, dicamba, carfentrazone, MCPA (Power Zone)	1.5-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + 4	72 - 87	
topramezone (Pylex)	0.023-0.034 fl oz/1000 sq ft POST	12	-	1 - 1	Do not apply to golf course collars or greens. Maintain a 5-ft buffer between treated areas and bentgrass greens. COC or MSO spray additive is required.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 7.5.3 – Pesticides labeled for treatment of Clover

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY†2, 4-D, triisopropanolamine salt, fluroxypyr, triclopyr (Momentum FX2)	1.1-1.5 fl oz/1000 sq ft POST	48	- + 4 + 4	6 - 8	Do not use on golf course greens or tees.
*NY†2,4-D dimethylamine salt, dicamba, fluroxypyr (Escalade 2)	0.75-1.1 fl oz/1000 sq ft POST	48	4 + 4 + 4	24 - 36	
2,4-D dimethylamine salt, MCPP, dicamba (Weed Beater)	4 fl oz/1000 sq ft POST	-	4 + 4 + 4	23	Not for use on sod farms or turf being grown for commercial seed.
2,4-D dimethylamine salt, MCPP, dicamba (Gordon's Trimec Ready to Spray Lawn Weed Killer)	6.4 fl oz/1000 sq ft POST	-	4 + 4 + 4	28	See label for specific setback distance restrictions from water bodies.
*NY†2,4-D, dimethylamine salt, dicamba, clopyralid (Millennium Ultra 2)	0.73-1.1 fl oz/1000 sq ft POST	48	4 + 4 + 4	19 - 29	Not for use on bentgrass greens and tees. Not for use on residential turf.
*NY†2,4-D, dimethylamine salt, MCPP, dicamba, sulfentrazone (Surge)	1.25-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4 + 14	21 - 25	Only one application per year of this product is allowed in New York state.
2,4-D, dimethylamine salt, triclopyr (Chaser 2 Amine)	1 fl oz/1000 sq ft POST	48	4 + 4	25	

Table 7.5.3 – Pesticides labeled for treatment of Clover

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY 2,4-D, dimethylamine salt, triclopyr (Turflon II Amine)	1 fl oz/1000 sq ft POST	48	4 + 4	25	
2,4-dichlorophenoxyacetic acid, dicamba, penoxsulam (Lesco Lockup Extra 2 with Fertilizer)	3.4-4 lbs/1000 sq ft POST	48	4 + 4 + 2	29 - 34	
Δ2,4-dichlorophenoxyacetic acid, MCPP, dicamba (Strike 3)	0.67-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4	13 - 30	
*NY †clopyralid (Lontrel T&O)	.125 - .2 fl oz/1000 sq ft POST	12	4	3 - 4	Not for use on residential turf.
*NY †clopyralid, 2, 4-D, triisopropanolamine salt, triclopyr (Riverdale XRM-5202)	1.1-1.5 oz/1000 sq ft POST	48	4 + - + 4	2 - 3	Do not use on golf course greens or tees.
*NY †clopyralid, triclopyr (Confront)	0.37 fl oz/1000 sq ft POST	48	4 + 4	6	Do not apply to putting greens or tees. In New York State, restricted to golf course use only.
dicamba, MCPA, triclopyr (Cool Power)	0.91-1.29 fl oz/1000 sq ft POST	-	4 + 4 + 4	57 - 81	Not for use in sod farms, or in seed production.
*NY †fluroxypyr, triclopyr (Tailspin)	1.1 fl oz/1000 sq ft POST	48	4 + 4	12	Do not use on golf course greens or tees.
MCPP, dicamba, 2, 4-D, triisopropanolamine salt (Trupower 3 Selective)	0.67-1.5 fl oz/1000 sq ft POST	48	4 + 4 + -	4 - 9	
MCPP, dicamba, carfentrazone, 2,4-D, 2-ethylhexyl ester (Speed Zone)	1.1-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + -	18 - 30	Do not apply to bentgrass greens.
MCPP, dicamba, carfentrazone, MCPA (Power Zone)	1.5-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + 4	72 - 87	
topramezone (Pylex)	0.023-0.034 fl oz/1000 sq ft POST	12	-	1 - 1	Do not apply to golf course collars or greens. Maintain a 5-ft buffer between treated areas and bentgrass greens. COC or MSO spray additive is required.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.5.3 – Pesticides labeled for treatment of Clover

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments

* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 7.5.4 – Pesticides labeled for treatment of Common perennial broadleaf weeds (e.g. dandelion, plantain)

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY†2, 4-D, triisopropanolamine salt, fluroxypyr, triclopyr (Momentum FX2)	1.1-1.5 fl oz/1000 sq ft POST	48	- + 4 + 4	6 - 8	Do not use on golf course greens or tees.
*NY†2,4-D dimethylamine salt, dicamba, fluroxypyr (Escalade 2)	0.75-1.1 fl oz/1000 sq ft POST	48	4 + 4 + 4	24 - 36	
*NY†2,4-D, dimethylamine salt, dicamba, clopyralid (Millennium Ultra 2)	0.73-1.1 fl oz/1000 sq ft POST	48	4 + 4 + 4	19 - 29	Not for use on bentgrass greens and tees. Not for use on residential turf.
*NY†2,4-D, dimethylamine salt, MCPP, dicamba, sulfentrazone (Surge)	1.25-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4 + 14	21 - 25	Only one application per year of this product is allowed in New York state.
*NY2,4-D, dimethylamine salt, triclopyr (Turflon II Amine)	1 fl oz/1000 sq ft POST	48	4 + 4	25	
Δ2,4-dichlorophenoxyacetic acid, MCPP, dicamba (Strike 3)	0.67-1.5 fl oz/1000 sq ft POST	48	4 + 4 + 4	13 - 30	
*NY†clopyralid (Lontrel T&O)	.25 - .5 fl oz/1000 sq ft POST	12	4	5 - 10	Not for use on residential turf.
*NY†clopyralid, 2, 4-D, triisopropanolamine salt, triclopyr (Riverdale XRM-5202)	1.1-1.5 oz/1000 sq ft POST	48	4 + - + 4	2 - 3	Do not use on golf course greens or tees.

Table 7.5.4 – Pesticides labeled for treatment of Common perennial broadleaf weeds (e.g. dandelion, plantain)

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY†clopyralid, triclopyr (Confront)	0.55-0.74 fl oz/1000 sq ft POST	48	4 + 4	9 - 12	Do not apply to putting greens or tees. In New York State, restricted to golf course use only.
dicamba, MCPA, triclopyr (Cool Power)	0.91-1.29 fl oz/1000 sq ft POST	-	4 + 4 + 4	57 - 81	Not for use in sod farms, or in seed production.
*NY†fluroxypyr, triclopyr (Tailspin)	2.2 fl oz/1000 sq ft POST	48	4 + 4	24	Do not use on golf course greens or tees.
iron HEDTA (Fiesta)	12.6-50 fl oz/1000 sq ft POST	-	-	Not Availab le	Reduced risk herbicide requiring determination of 'emergency application' for New York State school grounds and day care centers.
MCPP, dicamba, 2, 4-D, triisopropanolamine salt (Trupower 3 Selective)	0.67-1.5 fl oz/1000 sq ft POST	48	4 + 4 + -	4 - 9	
MCPP, dicamba, carfentrazone, 2,4-D, 2-ethylhexyl ester (Speed Zone)	1.1-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + -	18 - 30	Do not apply to bentgrass greens.
MCPP, dicamba, carfentrazone, MCPA (Power Zone)	1.3-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + 4	63 - 87	
mesotrione (Tenacity)	5-8 fl oz/acre POST	12	27	2 - 4	Do not use on golf course putting greens and maintain a five foot buffer between treated areas and putting greens.
topramezone (Pylex)	0.023-0.034 fl oz/1000 sq ft POST	12	-	1 - 1	Do not apply to golf course collars or greens. Maintain a 5-ft buffer between treated areas and bentgrass greens. COC or MSO spray additive is required.

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
Δ - Rate and/or other application restrictions apply. See label for more information.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 7.5.5 – Pesticides labeled for treatment of difficult to control broadleaf weeds (e.g. violets, ground ivy, etc.)

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
*NY†2,4-D, dimethylamine salt, MCPP, dicamba, sulfentrazone (Surge)	4-5 pts/acre POST	48	4 + 4 + 4 + 14	24 - 30	Only one application per year of this product is allowed in New York state.
*NY†clopyralid, 2, 4-D, triisopropanolamine salt, triclopyr (Riverdale XRM-5202)	1.1-1.5 oz/1000 sq ft POST	48	4 + - + 4	2 - 3	Do not use on golf course greens or tees.
*NY†clopyralid, triclopyr (Confront)	0.74 fl oz/1000 sq ft POST	48	4 + 4	12	Do not apply to putting greens or tees. restricted to golf course use only.
*NY†fluroxypyr, triclopyr (Tailspin)	1.65-2.2 fl oz/1000 sq ft POST	48	4 + 4	18 - 24	Do not use on golf course greens or tees. Repeat treatment may be necessary.
MCPP, dicamba, carfentrazone, 2,4-D, 2-ethylhexyl ester (Speed Zone)	1.1-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + -	18 - 30	Do not apply to bentgrass greens.
MCPP, dicamba, carfentrazone, MCPA (Power Zone)	1.5-1.8 fl oz/1000 sq ft POST	48	4 + 4 + 14 + 4	72 - 87	

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ
* - Restricted-use pesticide. Restricted use pesticides may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
*NY - Restricted-use pesticide in New York State.
† - Not for use in Nassau and Suffolk Counties. Pesticide labels that indicate 'Not for use on Long Island, NY' mean that use is prohibited in Nassau and Suffolk Counties only.

Table 7.5.6 – Pesticides labeled for treatment of Silvery thread moss

Active Ingredient (Trade Name)	Product Rate/Application Timing	REI[1] (Hours)	WSSA[2]	Field Use EIQ[3]	Comments
carfentrazone-ethyl (Quicksilver T&O)	0.154 fl oz/1000 sq ft	-	14	2	

[1]REI – Restricted Entry Interval. Only pertains to agricultural uses of the product.
[2]WSSA codes represent the mechanism of action as classified by the Weed Science Society of America (http://wssa.net)
[3]Field Use EIQ - A value comparing environmental impact of active ingredients to one another. Refer to section 1.13 for more information on Field Use EIQ

Table 7.5.7 - Examples of broadleaf herbicide combinations.

Trade name	Common name
*[NY]Chaser, Chaser 2 Amine	2,4-D plus triclopyr
*[NY]†Escalade 2	2,4-D + dicamba + fluroxypyr
*[NY]†Millennium Ultra 2	2,4-D + dicamba + clopyralid
*[NY]†Momentum FX2	2,4-D + triclopyr + fluroxypyr
Speed Zone	2,4-D + carfentrazone +dicamba + MCPP
Power Zone	MCPA + carfentrazone +dicamba + MCPP
Three-way Selective	2,4-D + dicamba + MCPP
Trimec Classic	2,4-D + dicamba + MCPP
*[NY]Turflon D	2,4-D plus triclopyr
Weedone	2,4-D plus 2,4-DP
*[NY]†Battleship III	MCPA + triclopyr + fluroxypyr
Trupower 3 Selective	MCPA + dicamba + clopyralid
[Δ]Strike 3	2,4-D + 2,4-DP + fluroxypyr
*[NY]†Surge	2,4-D + sulfentrazone + dicamba + MCPP
Cool Power	MCPA + triclopyr + dicamba

* Restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
† Not for use in Nassau and Suffolk Counties
Δ Rate and/or other application restrictions apply in New York State. See label for more information.

Table 7.5.8 - Weed response to selective postemergence herbicides[1].

	Weeds				
Trade name	***Dandelion***	***Clover***	***Ground Ivy***	***Violet***	***Plantain***
Buctril	E	E	F	F	G
*[NY]†Confront	F-G	E	G	G	E
Cool Power	E	G	E	G	E
*[NY]†Lontrel	G	E	P	-	F
*[NY]†Millennium Ultra 2	E	E	E	G	E
Powerzone	E	E	G	G	E
Speedzone	E	E	G	G	E
*†Spotlight	E	E	E	–	E
*[NY]†Surge	E	E	F	F	E
Trimec Classic	E	E	F	F	E
*[NY]Turflon Amine	E	E	E	E	G
2,4-D Amine	E	P	P	P	G

[1] E= excellent (>85% control), G=good (75-85% control), F=fair (65-75% control), P=poor (<65% control)
* Restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.
† Not for use in Nassau and Suffolk Counties
Δ Rate and/or other application restrictions apply in New York State. See label for more information.

7.6 Moss Control

7.6.1 Moss Control in Putting Greens

Bryum argenteum, silvery thread moss, is a significant pest problem on golf courses throughout the US. Superintendent surveys conducted by Cornell University researchers indicate that close mowing and surface organic matter accumulation are highly correlated with increased moss invasion. Additionally, observations suggest that the lack of metal-based fungicides, particularly mercury (Hg), have led to persistent moss invasion.

Postemergence control programs have been reported with variable success. Here at Cornell University we built upon observations from Oregon State University to develop consistent postemergence moss control programs with copper hydroxide based materials such as *[NY]Junction. Research has determined that four to seven applications of 4 ounces of *[NY]Junction applied between October and December at two-week intervals in 2 gallons of water per 1000 square feet provide consistent moss control.
The research has also shown that as spray solution pH decreases, bentgrass injury (yellowing) increases. Tissue samples showed that iron uptake is reduced when compared to untreated tissue iron levels. A follow up application of iron sulfate seems to reduce the yellowing and increases iron tissue levels, but more work is needed to determine the role of iron and injury.

A second series of experiments were conducted to evaluate *Terracyte, a sodium perchloride and lime based product for moss control. Spring applications were slightly less effective than fall treatments for moss control. This is consistent with observations of *[NY]Junction efficacy on moss. Apparently moss begins an acclimation period in response to day-length and temperature. This acclimation either enhances susceptibility or reduces the recuperative ability of the moss.

Recently, Quicksilver (carfentrazone) has been labeled for selective moss control in bentgrass golf course putting greens. Carfentrazone is a contact herbicide with little or no residual activity that provides selective postemergence control of broadleaf weeds and silvery thread moss (*Bryum argenteum*) in turfgrass. It is an aryl triazolinone herbicide, which interrupts chlorophyll synthesis and produces metabolic byproducts that disrupt plant cell membranes. This process occurs only in susceptible green plants in the presence of light. Symptoms may appear on foliage in 24 hr. or less in susceptible plants. Complete desiccation and death occur 7 to 14 days after application. QuickSilver is rainfast within 1 hr. after application. Established cool-season grasses generally tolerate applications at labeled rates. Recovery typically is within 4 to 7 days. If such injury cannot be tolerated, apply to a small test area before treating a large area.

QuickSilver produces herbicidal symptoms only in the weed parts it contacts directly. For best results, select a spray volume and nozzle system that ensures thorough, uniform coverage and minimizes fine spray droplets. Spray droplets larger than 400 microns may reduce coverage and reduce weed control. Apply in spray volumes of 20 to 175 gal/A (0.5 to 4 gal/100 sq. ft.). Use higher spray volumes on dense weed populations, turfgrass canopies, or where uniform coverage is difficult to obtain. QuickSilver can be applied, at 7 days or more after emergence, to creeping bentgrass.

7.6.2 Lawn Moss Control

Mosses are an increasing problem, currently flirting with invasive plant status in NY. Although mosses are a significant lawn pest, surprisingly little is known about them. Only about a dozen species have been identified worldwide. Moss growth normally starts with fall rains and reaches a peak in early spring. Because most grasses grow poorly in winter, mosses are able to invade and often dominate lawns in only a few months.

Moss growth declines in summer as conditions become drier and turfgrass growth increases, but under shady, irrigated conditions moss may grow through summer. Moss can tolerate long periods of drought in a dehydrated condition and rehydrate and grow with the onset of fall rains.

Cultural control: Although moss will invade well-maintained lawns, it usually occurs extensively in neglected lawns where cultural conditions enable it to out-compete turf. Moss encroachment generally is associated with thin turf, low fertility, highly acidic soils, shade, wet soils, and turf injury from insects, diseases, chemicals, or cultural practices. Long-term moss control is impossible unless these conditions are corrected.

Often turf is thin because it lacks fertilizer. Properly timed nitrogen fertilizer applications will increase turf density, vigor, and competitiveness. Liming soil to raise the pH to between 6.0 and 6.5 will benefit some grasses in the long run but will have no direct effect on moss.
Grasses grow poorly in dense shade because of low light and increased disease activity. Therefore, shady lawns usually have more moss than lawns in full sun. Thinning out trees by selective pruning or removing trees completely may reduce moss encroachment. In some cases, it's easier to redesign the area and eliminate turf than it is to improve lighting. When planting new lawns in shady sites, be careful to select shade-tolerant species. In relatively dry shade, the fine fescues perform well. In wet, shady sites, roughstalk bluegrass persists better than other grasses.

Wet soils caused by poor drainage or excessive irrigation provide a perfect environment for germination and growth of moss spores or plant fragments. Poor drainage sometimes can be improved by promoting water infiltration by core cultivation, slicing, or thatch removal. These practices also improve turfgrass vigor and competitiveness.

Often drainage can be improved only by changing grading or installing subsurface drain tubing to lower the water table. Wet soils often are due to excess irrigation. Avoid nightly watering, particularly in fall or early spring when moss growth is vigorous.

Thin turf, caused by injury, is a common contributor to moss encroachment. Unirrigated lawns turn brown and thin out during summer. When fall rains come, these lawns may not recover fast enough to compete with moss.

Severe dethatching in fall also may predispose the lawn to moss because turf is thin when fall rains come. Proper culture, which promotes healthy, dense turf during the moss season, reduces moss encroachment in most situations.

Mechanical control: Moss can be removed by dethatching in early spring. Optimum timing is mid-March through April, when moss is still healthy and vigorous. With a flail type dethatcher (available at rental agencies), as much as 75 percent of the moss can be removed. After dethatching, fertilize the lawn with nitrogen to stimulate turf growth and increase grass density. Where moss has invaded extensively, apply chemical sprays after dethatching to increase control.

Chemical control: Many chemical materials effectively kill moss in lawns. Most commercial formulations contain metals such as iron (Fe), copper (Cu), or zinc (Zn) as the active ingredient. Cryptocidal (mosskilling) soaps also are available. All of these materials can kill moss, but some are more effective than others.

Iron compounds are highly effective moss killers in turf. These compounds work quickly, and the iron stimulates a "green-up" of turf. Complete fertilizers with iron efficiently remove moss and stimulate grass growth, which improves turf appearance. Iron stains concrete and many other surfaces, so it must be applied carefully. Salts and chelated iron products applied as liquids work well on moss when used at rates of 1/2 to 1 pound of iron per 1,000 square feet. Dry formulations of fertilizer-plus-iron products are generally effective at rates of 0.8 to 1.5 pounds of iron per 1,000 square feet. The key to effective control with iron compounds is thorough coverage of moss foliage. Liquid materials are very effective and give almost instant results. Dusty fertilizer-plus-iron products are more effective than clean granular products because they provide better coverage of the moss.

Cryptocidal soaps are relatively new chemicals for moss control. Soaps act as contact killers and tend to bleach the moss to a whitish yellow, in contrast to the dark brown of moss treated with iron. Soaps are safe on sidewalks and other structures. Typical application rates for cryptocidal soaps are 2.5 quarts of product per 1,000 square feet.

Copper and zinc will remove moss on roofs and walks and will not stain structures. Unfortunately, compounds containing these elements act slowly as moss killers and can injure desirable turf grasses in lawns.

7.7 Alternative Weed Management

7.7.1 NYS Regulatory Policies

In the past 12 years, NYS has passed laws that restrict herbicide use on playing fields and lawns. Since 2000, the Neighbor Notification Law (Chapter 285 of the Laws of 2000) requires 48-hour notice of certain chemical applications on lawns. As of 2008, the counties of Albany, Erie, Monroe, Nassau, Rockland, Suffolk, Tompkins, Ulster, and Westchester Counties, and New York City have opted-in to the Neighbor Notification Law, which is determined at the county level. Required signage or notification is needed to indicate a pesticide application, except for pesticides exempt from the Neighbor Notification Law. Starting in 2010, a statewide law (Chapter 85, Laws of 2010) bans all pesticides on school grounds and day care centers not meeting EPA exemption under 25(b) FIFRA. Regulatory policies continue to shape NYS's weed management options, as pressure to minimize environmental and human health risks remain strong.

7.7.2 Demand for Alternative Weed Control

New regulatory policies affecting pesticide use create much of the demand for alternatives in weed management. Environmental and human health concerns from individuals, community groups, and public interest organizations create additional demands for alternative weed control across a variety of turf landscapes. In 2010, the NYS DEC initiated the Be Green Organic Yards NY training and licensing program for organic lawn care businesses and service providers. Be Green businesses adhere to organic lawn practices that prohibit the use of certain pesticides. The Northeast Organic Farmers Association (NOFA) provides a larger network of organic lawn care businesses through an accreditation program for land care professionals. More information can be found at www.organiclandcare.net.

7.7.3 Emerging Techniques in Weed Control

Cornell turf researchers have developed several management techniques that minimize or suppress weed occurrences in many turf settings. Drs. Frank Rossi and Jennifer Grant have created a model for reduced pesticide use on golf courses using Bethpage State Park Golf Course as the demonstration system. The manual "Reducing Chemical Use on Golf Courses – Redefining IPM" is offered in both English and Spanish. For lawns and playing fields, Dr. Frank Rossi, David Chinery (Rensselaer CCE) and Walt Nelson (Monroe CCE) developed a repetitive fall seeding program that relies on seeding existing turf with perennial ryegrass. The method relies on frequent seeding every one or two weeks ranging from late August until October. Irrigation or rainfall is important for seed germination. Under no irrigation or minimal rainfall low, the recommendation is 4 to 6 lb. per 1,000 sq. ft. With adequate moisture, only 2 to 4 lb. per 1,000 sq. ft. is needed. They found frequency to be the key in creating a dense turf of perennial ryegrass. In one study, a significant reduction in crabgrass was observed throughout the following growing season in a playing field. Research by Drs. Andy Senesac and Frank Rossi showed reduced weed cover in turf receiving nitrogen fertilization treatments as a result of improved turf density. Nitrogen addition in the spring showed similar weed suppressive abilities compared with adding corn gluten meal as a preemergent herbicide. Dr. Leslie Weston discovered an allelochemical (m-tyrosine) exuded from the roots of different cultivars of fine fescues that reduce weed populations. Ongoing research by Dr. Martin Petrovic includes testing fine fescue turf for lawn installments.

Mechanical weeding is gaining popularity as a method to control young weeds and annual plants when chemical use is restricted. Examples include propane torches, steam and hot water systems, weed whackers, and a variety of tools for hand weeding.

7.7.4 EPA Exempt (25(b) FIFRA) Herbicides Allowable for Use on School Grounds and Daycare Centers

Under NYS Law Chapter 85, Laws of 2010, all schools and day care centers must comply with restrictions on pesticide use. The law restricts use of pesticides to products containing active ingredients listed as exempt under FIFRA 25(b). (These pesticides must include inert ingredients that are listed under 4a of the FIFRA 25(b) exemption.) Pesticides containing any active or inert ingredients not qualifying as FIFRA 25(b) exempt must receive one-time emergency application approval from the appropriate channels. Approval of a one-time emergency application of a pesticide is determined by the following: 1) All public schools seek approval from their local school board; 2) All private schools and day care centers receive approval from the county department of health (DOH), State DOH district office, or the state DOH's Bureau of Toxic Substance Assessment; 3) Non-public schools and day care centers may get approval for an emergency application from the NYS DEC where there is an environment-related issue. See the NYS DEC's web site for more information (www.dec.ny.gov/chemical/41822.html).

The postemergence herbicides that qualify under the EPA exemption of 25(b) FIFRA work primarily as defoliants that knock down the leaf and stem tissues of plants in contact with the herbicide. For perennials, roots and rhizomes are generally able to regrow in several weeks, requiring 2 to 3 applications in a season. See tables 7.5.4 and 7.5.5 for lists of herbicides allowable on school grounds and day care centers.

Table 7.7.4 Minimum-risk herbicides allowed under the NYS Child Safe Playing Fields Act.

Trade Name	Active Ingredient	Product Rate/Timing of Application	Comments
Adios	sodium chloride	1-1.5 lbs/gal water POST	25(b) pesticide
Brush, Weeds, and Grass Herbicide	citric acid	See label for rates POST	25(b) pesticide
Burnout II	citric acid & clove oil	1:2 or 1: 3 dilution with water POST	25(b) pesticide
C-cide	citric acid & clove oil	1:3 dilution with water POST	25(b) pesticide
GreenMatch EX	lemon grass oil	7-10 gal/100 gal water POST	25(b) pesticide
Matran EC	clove oil	5-8 gal/100 gal water POST	25(b) pesticide
Matratec	clove oil	5-8 gal/100 gal water POST	25(b) pesticide
Phydura	citric acid, malic acid, clove oil	1:2 or 1:3 dilution with water POST	25(b) pesticide
Weed Zap	clove and cinnamon oils	5 gal/100 gal water POST	25(b) pesticide
WOW Supreme	corn gluten	10 lbs/ 1000 sq ft PRE	25(b) pesticide

8 Wildlife Management for Turfgrass

8.1 Moles

Moles are small, insect-eating mammals that are highly specialized for life underground. Moles have very small eyes, no external ears, a hairless, pointed snout, and forefeet that are enlarged and turned outward for digging in the soil. The two most common species in New York State are the star-nosed mole (*Condylura cristata*), and the hairy-tailed mole (*Parascalops breweri*). The eastern mole (*Scalopus aquaticus*) occurs in the lower Hudson River Valley and Long Island. All three species have short, thick, dark velvety fur that lies flat in either direction as the mole makes its way through a burrow system. The eastern mole grows to be up to 6 1/2 inches long and has a naked tail. The hairy-tailed mole grows to be up to 5 1/2 inches long and has a short, hairy tail. The star-nosed mole reaches 5 inches in length, and has a nose surrounded by 22 small, fingerlike projections around its nose, which readily distinguishes it from other moles. These last two species are found throughout the state, and all moles are legally classified as unprotected animals in New York State.

8.1.1 General Biology and Food Habits

Moles spend most of their lives within extensive systems of underground tunnels where a circular nest chamber is excavated and lined with leaves and grass. They produce a single litter of three to seven young each year in April or May after a gestation period of about 42 days. Young moles leave the nest in four to five weeks.

Moles are primarily insectivorous, feeding on insect larvae (including grubs), earthworms, or other invertebrates encountered while digging in the soil. They consume from 70 to 100 percent of their body weight each day in order to supply their energy demands. Therefore, moles can be very beneficial mammals, as they remove many damaging insects and grubs from lawns and gardens. Occasionally, moles may feed on seeds, roots or bulbs.

Moles prefer loose, moist soil in fields and woods shaded by vegetation. Hairy-tailed moles tend to occupy fairly well-drained but moist sandy loam, whereas star-nosed moles tend to occur in low, wet ground especially near open water. Moles have two types of burrow systems, shallow and deep. Deep systems are fairly permanent, located 6-24 inches below the surface, and are used for cover and for raising young. Shallow systems are more temporary and are used as runways while foraging just below the soil surface.

Burrowing moles occasionally damages lawns, gardens and golf greens, uprooting plants as they tunnel through the soil in search of food. Moles can leave volcano-shaped hills of soil that are pushed up from their deep tunnels. Surface ridges in the soil also indicate mole activity.

8.1.2 Population Control

Because moles are not prolific breeders and do not occur in high population densities, removing just one or two moles will often solve damage problems. The best time to conduct mole control is in the spring and fall when soil moisture levels are higher but the ground is not frozen. The most effective way to control mole damage is to use special body-gripping, scissor-jawed, or harpoon mole traps designed to kill moles as they move through their tunnels. Mole traps of several types can be purchased in garden or farm-supply stores.

Before setting a trap, locate a surface tunnel that appears to be active. Depress part of the tunnel with your foot and return the following day. If the tunnel has been repaired, then it is an active tunnel and a suitable place to set a trap. If the tunnel has not been repaired, then it is probably not active. Once you have found a suitable location, depress a portion of the tunnel with your foot again and set the trap over the depressed area. As the mole moves through the tunnel it will push upward on the depressed tunnel roof and trip the trigger of the trap. Hairy-tailed and star-nosed moles may have sub-surfaces tunnels, and traps may need to be placed below ground surface level.

8.1.3 Toxicants

A number of different toxicants (Table 8.1.1) are available commercially and legally registered for use against moles in New York State. The active ingredient in most of these products is zinc phosphide, a restricted use pesticide that may be purchased and used only by certified pesticide applicators. Zinc phosphide baits often are ineffective because of the difficulty of getting moles to feed on baits rather than the invertebrates that they prefer. Always check the label on any pesticide to make sure it is registered for use on lawns, golf courses, or other turf areas.

8.1.4 Cultural Practices

Use of insecticides on lawns to reduce the food supply of moles is often touted as a remedy for mole damage. Although insecticides may reduce the food supply in light, sandy soils, they will have little effect in heavy clay soils. In addition, treatment of a single lawn or small area will be ineffective, as moles may still burrow through the treated area in search of food. Moles may also move into the area from adjacent untreated areas. Studies indicate that routine use of insecticides on lawns for "prevention" purposes kills off predator insects that keep lawn pests under control naturally, and should be avoided.

Table 8.1.1 Toxicants and repellants registered in NYS for controlling mole damage to turfgrass

Trade Name	Active Ingredient	Product Rate	Comments
Agway Mole Control	zinc phosphide	1 tsp/hole	
Bonide Moletox II	zinc phosphide	1 tsp/hole	
Gordon's Mole & Gopher Killer Poison Pellets	zinc phosphide	1 tsp/hole	
Prozap Mole & Gopher Pelleted Bait	zinc phosphide	1 tsp/hole	
*Talpirid	bromethalin	1 worm shaped bait/hole	This product may only be used in non-crop grassy areas to control eastern moles (Scalopus aquaticus) and star-nosed moles (Condylura cristata parva).

***Restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.**

8.2 Striped Skunks

The striped skunk *(Mephitis mephitis)* is a member of the weasel family (Mustelidae), well-known for the potent, musky odor it emits from its anal glands as a defense. The size of a large house cat, the skunk is jet black in color with a prominent white stripe that begins at the back of the head and splits into two lateral stripes that run down the back and sometimes onto the tail. Its body is stout, with a triangular head, round ears, and a long bushy tail that accounts for almost half its body length (20-30 inches). The skunk provides ecological and economic benefits to us because they eat rodents and insects.

Skunks are protected furbearers in New York and there are established hunting and trapping seasons. A license is required before trapping skunks unless they are causing damage or have become a nuisance. Current New York State Environmental Conservation Law (Section 11-0523) states that skunks injuring property, or are a nuisance, may be taken at any time in any manner. Any skunks taken under these laws and outside the open season must be immediately buried or cremated or released alive somewhere on the property. Licensed nuisance wildlife control operators may transport wildlife off of the property but do so for a fee. Contact your local Department of Environmental Conservation office for the name of a licensed nuisance wildlife control operator in your area.

When shooting or trapping to manage skunk problems, you must follow local ordinances, so it is best to consult with local law enforcement authorities or regional Department of Environmental Conservation offices if you have questions regarding specific localities.

8.2.1 General Biology and Food Habits

Skunks mate in late February through late March and, after a gestation period of 62 to 75 days, give birth to four to six young in May or early June. Young skunks begin to walk when they are five weeks old and are completely weaned by two months. At this age, they begin leaving the den to accompany their mother on hunting trips. By the time they are three months old, the young are independent. Musk is present in skunks at birth. However, young skunks cannot raise their tails and eject it until they are three weeks old. Skunks are mild-mannered, non-aggressive animals with poor sight, hearing and sense of smell. They will often ignore intruders even in close proximity unless disturbed. When cornered or closely pursued they will face the intruder, arch their backs, raise their tails, stamp the ground with their feet, and shuffle backwards. Just before spraying the skunk bends into a u-shape so that both head- and tail-ends face the intended target. The musk is released as either a fine spray or as a stream of drops and can reach distances up to 16 feet. In winter skunks do not truly hibernate, but they become inactive, falling into a deep sleep for long periods (up to six weeks) during the winter. They do emerge periodically during winter when there is a break in cold weather. Skunks may lose up to 38% of their body weight during the winter. In the wild, skunks live only about two years.

The striped skunk prefers clearings, cropland, pastures, and other types of open lands bordering wooded or brushy areas. Skunks are nocturnal and spend their nights searching for food along woodland, brushland or wetland borders, along fencerows or wooded ravines, or near stream edges. During the day skunks den in abandoned woodchuck or fox burrows, culverts or hollow logs, or under lumber piles, porches, sheds and other outbuildings. Although skunks are not sociable animals, in the winter for warmth two to seven females may den with one male.

Skunks remain within a small area for most of their lives, usually within 1 mile of their den. However, male skunks may travel greater distances during the breeding season.

Skunks are omnivorous and have a highly variable diet that changes throughout the seasons. Foods include plants, berries, insects, crustaceans, small mammals, birds, eggs, amphibians, fish, and carrion. Like many other animals, skunks are opportunists, eating garbage and pet food left outdoors in urban and suburban areas.

8.2.2 Description of Damage

Most people fear skunks because of their nauseating odor. The odor can be experienced when a skunk takes up residence under building foundations, under porches or outbuildings, or in someone's yard. However, skunks will not spray unless they feel threatened. When confronting a skunk, avoid loud noises and quick movements. Back away slowly and quietly to avoid getting sprayed.

In addition to odor concerns, skunks cause other types of damage. Skunks may damage turf in yards and golf courses when they dig for grubs, leaving small upturned patches of sod and 3-4 inch funnel-like holes dug into the soil. Occasionally, skunks will dig up and consume hives of ground-nesting bees. Most damage occurs in late spring and early summer when the soil is moist.

8.2.3 Population Reductions

Live traps (10 x 10 x 30 inches in size) baited with sardines, fish-flavored cat food, or peanut butter can be set near the den entrance to capture skunks. Although skunks can be captured using live traps, most homeowners do not want to assume the risk of being sprayed that comes with close contact with a skunk. Because New York Environmental Conservation Law prohibits anyone except nuisance wildlife control operators or wildlife rehabilitators from transporting live-captured animals, the landowner must euthanize skunks captured on his or her property or release them alive elsewhere on the property. To avoid the risk of being sprayed, contact a professional to handle your skunk problems.

8.2.4 Pesticides

No toxicants, fumigants or repellents are currently registered in New York State for skunk control.

8.2.5 Cultural Practices

You can take several simple steps to minimize the attractiveness of your property to skunks. Remove obvious sources of food or shelter. Lumber and debris piles may encourage skunks to use an area. Avoid leaving pet food outside, and store garbage in metal or plastic containers with tight-fitting lids. Cover compost piles to reduce their attractiveness to skunks and prevent skunk feces from entering the compost. Skunks are often attracted to rodents living in barns, sheds, garages and other areas. Reducing rodent populations can eliminate this attraction. Clean up spilled seed around bird feeders that may attract rodents and skunks.

8.2.6 Health Concerns

Skunks are an important rabies vector in North America. Rabies is a deadly disease caused by a virus that attacks the nervous system. Animals most often infected include raccoons, skunks, foxes, and bats. The virus is present in the saliva and nervous tissue of a rabid animal. Be particularly cautious of animals that act strangely, especially those that are unusually tame, aggressive, or appear to be paralyzed. Be suspicious of daytime activity in skunks, which are usually most active at night.

If you or someone you know is bitten or scratched by a skunk, wash the wound thoroughly with soap and water and contact your physician immediately. Rabies post-exposure vaccinations may be necessary. Consult with your county health department, the NYS Bureau of Communicable Disease Control (518-474-3186), or during evenings and weekends, the NYS Department of Health duty officer (518-465-9720) for additional information.

8.3 Canada Geese

Canada geese are a valuable natural resource that provides recreation and enjoyment to bird watchers, hunters, and the public. In recent years, flocks of local-nesting or “resident” geese have become year-round inhabitants of our parks, waterways, residential areas, and golf courses, where they can cause significant problems.

In suburban areas throughout New York State, expanses of short grass, abundant lakes and ponds, lack of natural predators, limited hunting, and supplemental feeding have created an explosion in resident goose numbers. While most people find a few geese acceptable, problems develop as local flocks grow and the droppings become excessive (a goose produces a pound of droppings per day). Problems include over-grazed lawns, accumulations of droppings and feathers on play areas and walkways, nutrient loading to ponds, public health concerns at beaches and drinking water supplies, aggressive behavior by nesting birds, and safety hazards near roads and airports.

All Canada geese, including resident flocks, are protected by Federal and State laws and regulations. In New York, management responsibility for Canada geese is shared by the U.S. Fish and Wildlife Service (USFWS), U.S. Department of Agriculture (USDA), and the New York State Department of Environmental Conservation (DEC). It is illegal to hunt, kill, sell, purchase, or possess migratory birds or their parts (feathers, nests, eggs, etc.) except as permitted by regulations adopted by USFWS and DEC.

8.3.1 Population Growth

In the early 1900s, only a handful of Canada geese nested in the wild in New York State. These geese were descendants of captive birds released by private individuals in the Lower Hudson Valley and on Long Island. Local flocks grew rapidly and spread to other areas. During the 1950s and 1960s, game farm geese were released by the State Conservation Department on wildlife management areas north and west of Albany. By the mid-1990s, the New York State population had grown to more than 120,000 birds, with nesting documented all across the state. The estimated number of geese breeding in New York doubled between 1989 and 1998.

8.3.2 Goose Biology

Resident geese are long-lived in suburban areas. Some will live more than 20 years. Most geese begin breeding when they are 2-3 years old and they nest every year for the rest of their lives. They mate for life, but if one member of a pair dies, the other will mate again. Geese lay an average of 5 eggs per nest, and half will hatch and become free-flying birds in the fall. A female goose may produce more than 50 young over her lifetime.

The annual life cycle for geese begins in late winter when adult pairs return to nesting areas in late February or March, as soon as waters open up. Egg laying and incubation generally extend through April, with the peak of hatching in late April or early May, depending on location in the state. Geese will aggressively defend their nests, and may attack if approached. Non-breeding geese often remain nearby in feeding flocks during the nesting season. After hatching, goose families may move considerable distances from nesting areas to brood-rearing areas, appearing suddenly "out of nowhere" at ponds bordered by lawns.

After nesting, geese undergo an annual molt, a 4-5 week flightless period when they shed and re-grow their outer wing feathers. Molting occurs between mid-June and late July, and the birds resume flight in August. During the molt, geese congregate at ponds or lakes that provide a safe place to rest, feed and escape danger. Severe problems often occur at this time of year because the geese concentrate on lawns next to water. Some geese without young travel hundreds of miles to favored molting areas. These local migrations account for the disappearance or arrival of some local goose flocks in early June.

After the molt and through the fall, geese gradually increase the distance of their feeding flights and are more likely to be found away from water. Large resident flocks, sometimes joined by migrant geese in October, may feed on athletic fields and other large lawns during the day, and return to larger lakes and ponds to roost at night. This continues until ice or snow eliminates feeding areas and forces birds to other open water areas nearby or to the south, where they remain until milder weather returns and nesting areas open up.

"Resident" geese, as their name implies, spend most of their lives in one area, although some travel hundreds of miles to wintering areas. Resident geese are distinct from the migratory populations that breed in northern Canada. Banding studies have shown that resident geese are not simply migrant geese that stopped flying north to breed. In fact, Canada geese have a strong tendency to return to where they were born and use the same nesting and feeding sites year after year. This makes it hard to eliminate geese once they become settled in a local area.

8.3.3 Discouraging Geese

There are many ways to discourage Canada geese from settling in your area. No single technique is universally effective and socially acceptable. Persistent application of a combination of methods is usually necessary and yields the best results.

Goose problems in suburban areas are especially difficult because birds are not afraid of people and may become accustomed to scaring techniques. Also, some techniques are not compatible with desired uses of suburban properties. For example, loud noisemakers in residential areas, putting grid wires over swimming areas, or letting grass grow tall on athletic fields, are not practical remedies in those situations. But don't rule out any technique that might be feasible. Dogs under strict supervision can safely be used in parks and schools, and controlled hunting has been successfully used at some golf courses.

Initiate control measures as soon as you notice geese in your area and be persistent. Once geese settle in a particular location, they will be more tolerant of disturbances and be difficult to disperse. No method works well with just a few attempts, and a comprehensive, long-term strategy is usually needed. Control measures work in various ways. Some reduce the biological capacity of an area to support geese by reducing availability of food or habitat. Other methods disperse geese to other sites where, hopefully, they are of less concern. Some techniques reduce the actual number of geese to a level that people can tolerate ("social carrying capacity"). Control techniques described here include those that have the best chance for success based on past experience.

8.3.4 Discontinue Feeding

Although many people enjoy feeding waterfowl in parks and on private property, this often contributes to goose problems. Feeding may cause large numbers of geese to congregate in unnatural concentrations. Well-fed domestic waterfowl often act as decoys, attracting wild birds to a site. Feeding usually occurs in the most accessible areas, making a mess of heavily used lawns, walkways, roads, and parking areas. Supplemental feeding also teaches geese to be unafraid of people, making non-lethal control measures less effective. Feeding may be unhealthy for the birds too, especially if bread or popcorn becomes a large part of their diet. Once feeding is discontinued, geese will disperse and revert to higher quality natural foods. Geese that depend on human handouts are also less likely to migrate when severe winter weather arrives, and are more vulnerable to disease.

Supplemental feeding should be stopped as a first step in any control program. Some success in reducing goose feeding may be achieved through simple public education, such as posting of signs. Further reduction of feeding may require adoption and enforcement of local ordinances with penalties such as fines or "community service" (cleaning up droppings, for example) for violations.

8.3.5 Allow Hunting

Hunting in suburban areas is often limited by lack of open spaces and local ordinances prohibiting discharge of firearms. Where feasible, however, hunting can help slow the growth of resident goose flocks. Hunting removes some birds and discourages others from returning to problem areas. It also increases the effectiveness of noisemakers, because geese will learn that loud noises may be a real threat to their survival.

Canada goose hunting is permitted in most areas of New York State during September, when very few migratory geese from Canada are present. Hunting is also allowed in some areas later in fall and winter, but regulations tend to be more restrictive to protect migratory geese that may be in the state at that time.

To hunt waterfowl, a person must have a New York State hunting license (which requires a hunter safety course), a federal Migratory Bird Hunting Stamp, and be registered in New York's Harvest Information Program. Hunters should check local laws regarding discharge of firearms. Landowners concerned about potential conflicts can easily limit the number of hunters and times they allow hunting on their property. For more information about goose hunting regulations or setting up a controlled hunt, contact DEC.

8.3.6 Modify Habitat

Geese are grazing birds that prefer short, green grass or other herbaceous vegetation for feeding. Well-manicured lawns and newly seeded areas provide excellent habitat for these grazing birds. Wherever possible, let grass or other vegetation grow to its full height (10-14") around water bodies so that it is less attractive to geese. In time, geese may stop feeding in those areas. Instead of grass, plant or encourage native shrubs or less palatable ground cover, such as ivy, pachysandra, or junipers, around the shoreline of ponds and along walkways where geese are a problem. You can also plant grass species that are less palatable to geese, including some that go dormant in the winter. Geese tend to prefer Kentucky bluegrass, and are less attracted to fescue. Also, minimize use of lawn fertilizers to reduce the nutritional value of grass to the birds.

It is very difficult to eliminate goose nesting habitat. Geese rarely nest in open lawns where they feed. Typically, they build nests on the ground close to water, hidden by vegetation. However, geese are very adaptable and nest in a variety of habitats, including woodlands, flower gardens, and rooftops. Islands and peninsulas are preferred nesting sites, and often support many more nesting geese than mainland shorelines. Avoid creating such features during landscaping of ponds in problem areas. Local zoning regulations may be a way to discourage habitat developments that favor geese.

8.3.7 Install Low Wires over Ponds

Geese normally rest on open water or along shorelines to feel safe from predators. They also tend to land and take off from open water when feeding on adjacent lawns. Where practical, construct a system of suspended wires over the water to deny the birds' access to such areas. Single strands of #14 wire or 80-100 pound test monofilament line can be arranged in a grid with 10-15 feet between wires. Each wire must be secured so that it remains 12-18" above the water surface and perimeter fencing may be needed to keep geese from walking under the grid. To reduce the risk of birds flying into the wires, attach brightly colored rope, flagging or other markers to make them more visible.

Wire systems are not practical for ponds used for swimming, fishing, or other recreation. However, golf course ponds, reflecting pools, wastewater ponds, and newly seeded lawns with limited public access, may be suitable. Human disturbance (vandalism) of grid wires may be a problem in public areas.

8.3.8 Install Fencing during the Molting Period

Fencing or other physical barriers can be effective where geese tend to land on water and walk up onto adjacent lawns to feed or rest. Fencing works best during the summer molt (mid-June to mid-July), when geese are unable to fly and must walk between feeding and resting areas. In these situations, fencing or other physical barriers installed close to the water's edge are effective ways to control goose movements. Fences must completely enclose the site to be effective. Fencing may also be used to block aggressive birds on nests near buildings or walkways. Although birds can get around most fencing, direct attacks may be prevented. Fencing around large open areas, such as athletic fields or ponds, has little effect on free-flying birds.

Goose control fences should be at least 30" tall (48-60" to block aggressive birds) and solidly constructed. Welded wire garden fencing (2" x 4" mesh) is durable and will last years. Less expensive plastic or nylon netting is effective, but will have to be replaced more often. Fences may be beautified or hidden by planting shrubs close by. Snow fencing or erosion control fabric may be used as a temporary barrier to molting geese.

8.3.9 Use Visual Scaring Devices

Various materials may be used to create a visual image that geese will avoid, especially if they are not already established on a site, such as newly seeded areas. Geese are normally reluctant to linger beneath an object hovering overhead. However, visual scaring devices are not likely to be effective on suburban lawns where trees or other overhead objects exist and where geese have been feeding for years.

One very effective visual deterrent for geese is Mylar tape that reflects sunlight to produce a flashing effect. When a breeze causes the tape to move, it pulsates and produces a humming sound that repels birds. This product comes in 1/2"-6" widths. To discourage geese from walking up onto lawns from water, string the tape along the water's edge. To ensure maximum reflection and noise production, leave some slack in the tape and twist the material as you string it from stake to stake.

Another visual scaring technique is the placement of flagging or balloons on poles (6' or taller) or other objects in and around an area to be protected. Flagging can be made of 3-6' strips of 1" colored plastic tape or 2' x 2' pieces of orange construction flagging. Bird-scaring balloons, 30" diameter, with large eye-spots and helium filled, are sold at some garden or party supply stores. Numerous flags or balloons may be needed to protect each acre of open lawn. These materials should be located where they will not become entangled in tree branches or power lines. They also may be subject to theft or vandalism in areas open to the public. If geese become acclimated, frequent relocation of the materials is recommended. For small ponds, remote control boats can be used to repel geese, and may be practical if local hobbyists are willing to help out.

8.3.10 Use Noisemakers

Geese may be discouraged from an area through the use of various noisemakers or pyrotechnics. Shell crackers are special shells fired from a 12-gauge shotgun that project a firecracker up to 100 yards. Other devices, such as screamer sirens, bird-bangers, and whistle bombs, are fired into the air from a hand-held starter pistol or flare pistol. These devices generally have a range of 25-30 yards.

Noisemakers work best as preventive measures before geese establish a habit of using an area and where the birds are too confined to simply move away from the noise. At sites with a history of frequent use by geese and people, the birds may become acclimated in 1-2 weeks. Noise devices are often not effective for moving nesting geese.

Before using any of these techniques, check with local law enforcement agencies concerning noise control ordinances, fire safety codes, or restrictions on possession and discharge of firearms. Obtain special permits if necessary. In some areas, starter pistols are considered a handgun, and their possession and use may be regulated. Federal and State permits are not necessary to harass geese with these techniques, as long as the birds are not physically harmed.

Where discharge of firearms is allowed, occasional shooting of geese can increase the effectiveness of noisemakers, as geese associate the sound with a real threat. Special Federal and State permits are needed to shoot geese except during established hunting seasons.

8.3.11 Apply Repellents

The U.S. Environmental Protection Agency and DEC have approved the use of several goose repellents on lawns (Table 8.3.1). Geese will avoid feeding on treated lawns because they dislike the taste. However, geese may still walk across treated areas to get to adjacent untreated areas. The active ingredients include methyl anthranilate (MA) or anthraquinone. These materials are available at some garden supply centers and costs about $125 per acre per application. Several applications per year are usually necessary. Therefore, it is most practical and cost-effective for only small areas of lawn. For best results, follow directions on product labels; if too dilute, it won't work, if too concentrated, it can kill the grass. Repellents may not be used in ponds or wetlands in New York State, and a DEC Article 24 (Freshwater Wetland) permit is needed to apply it within 100 feet of a regulated wetland.

Table 8.3.1. Repellents registered in NYS for controlling goose damage to turfgrass.

Product Name	EPA Registration No.	Active Ingredient
Liquid Fence Goose Repellent	72041-2	20.7% Methyl anthranilate

8.3.12 Use Dogs to Chase Geese

Dogs trained to chase but not harm geese have been used effectively to disperse geese from golf courses, parks, athletic fields and corporate properties. Border collies or other breeds with herding instincts tend to work best. The dogs must be closely supervised during this activity. Except where permitted, compliance with local leash laws or park regulations is still required. Initially, chasing must be done several times per day for several weeks, after which less frequent but regular patrols will be needed. Geese will not become acclimated to the threat of being chased by dogs.

This method is most practical where the dog and handler are on-site at all times, or where daily service (as needed) is available from private handlers. Another approach is to allow dogs to roam freely in a fenced (above ground or "invisible" dog fence) area that is not open to the public, but this may be less effective. Dogs generally should not be used when geese are nesting or unable to fly, such as during the molt or when goslings are present. Use of dogs may not be practical near busy roads or where a property is divided into many small sections by fences, buildings, or other barriers. Also, dogs cannot easily repel geese from large water areas, but may be able to keep geese off shoreline lawns or beaches. Although this technique has proven effective, it is often expensive and labor intensive.

8.3.13 Laser Lights

Specially designed high-intensity lasers have been developed for bird control (e.g., Avian Dissuader™). These lights will disrupt roosting geese on ponds during the night. As for other scare devices, repeated use is necessary. It is very difficult to break the site fidelity of roosting geese. Most flocks can find safe havens where it is not possible to haze or scare the geese. Consequently, flocks will move back to favorite roosting ponds once the hazing activity has stopped.

8.3.14 Control Goose Nesting

Geese usually return in spring (late March) to the area where they hatched or where they nested previously. Over time, this results in increasing numbers of geese in areas that once had just a few birds. Local population growth may be controlled by preventing geese from nesting successfully. Although it is difficult to eliminate nesting habitat, harassment in early spring may prevent geese from nesting on a particular site. However, they may still nest nearby where they are not subject to harassment.

If nest prevention fails, treating the eggs to prevent hatching is an option. This can be done by puncturing, shaking, freezing or applying corn oil to all of the eggs in a nest. The female goose will continue incubating the eggs until the nesting season is over. If the nest is simply destroyed, or the eggs removed, the female may re-nest and lay new eggs. Federal and state permits are required to disrupt goose eggs or nests. Additional information on egg treatment will be sent to individuals who obtain a USFWS permit to control goose nesting on their property. To treat eggs with corn oil in New York State, the person must be a certified pesticide applicator, in addition to having the necessary state and federal permits.

Egg treatment helps in several ways. First, it directly reduces the number of geese that will be present on a site later in the year. Second, geese without young will be more easily repelled from a site after the nesting season. Finally, if conducted on a large enough scale (throughout a town), it can help slow the growth of a local goose population, and over time lead to stable or declining numbers. Egg treatment may be necessary for 5-10 years before effects on goose numbers are evident.

One fertility control chemical (nicarbizin; *OvoControl™) has been approved by US-EPA. This material requires repeated feeding of nesting geese during the egg-laying period. Additional field trials and applications are needed to determine the utility of this product.

8.3.15 Capture and Remove Geese

An effective method of relief for sites with problems during the summer, or to help reduce year-round goose numbers in an area, is capture and removal of geese. Federal and state permits are required for this activity. Geese are easy to capture during the molt by simply herding them into holding pens.

In large areas, it may be necessary to remove geese for several years to get maximum results. After geese are removed, the capture site will have substantially fewer geese for the rest of the summer or longer. Over time, geese from surrounding areas may move in if preventive measures are not in place.

Geese removed from problem areas can be processed and donated to charities for use as food. If properly handled by a licensed poultry processor, goose meat is a healthy and well received source of food for needy people. However, this method is very controversial. Media interest, protests and legal challenges from animal rights activists can be expected.

Relocation of geese is not an option at this time, and moving geese is less effective than permanent removal. Banding studies have shown that many relocated geese return to their initial capture locations by the following summer. Geese taken short distances (less than 50 miles) may return soon after they are able to fly. Adult geese are most likely to return, whereas goslings moved without parent birds will often join a local flock and remain in the release area. Birds that don't return may seek out areas similar to where they were captured, and may cause problems there too. Many wildlife and animal health professionals are concerned that relocating problem wildlife increases the risk that diseases may be spread to wildlife or domestic stock in other areas.

8.3.16 Not Recommended

For almost every method that has been tried to alleviate problems caused by geese, there has been success and failure. However, some methods were not recommended in this document for various reasons. These include: use of swans (real ones create other problems; fake ones don't work); bird distress calls (effective for some bird species, but not proven for geese); scarecrows or dead goose decoys (ineffective for resident geese); use of trained birds of prey to chase geese (labor-intensive, generally not available); sterilization (very labor-intensive for surgery); fountains or aerators in ponds (not effective, may even attract geese); introduction of predators (already present where habitat is suitable, but none take only geese); disease (impossible to control and protect other animals); and use of poisons (illegal).

8.3.17 "Community-Based" Goose Management

Simply chasing geese from one place to another does not address the underlying problem of too many geese, and may simply transfer the problem from one property owner to another. This is not an effective strategy for communities with widespread goose problems. Therefore, Cornell Cooperative Extension, DEC, and USDA encourage local governments and landowners to work together to implement comprehensive management programs that include a variety of techniques. Control measures will be most effective if coordinated among nearby sites in a community.

While some measures can be tried at little or no cost, others are more costly and beyond the means of some property owners. In these instances, local governments may want to sponsor goose control throughout a community, similar to other animal control work. This could include posting "no feeding" areas, installing fences, spraying repellent, handling dogs, egg treatment, and removal of geese. This way, the cost of goose management would be shared by all the residents of a community, including those who benefit from the geese as well as those who may experience problems. Although Federal and State agencies can provide technical advice, they do not have the resources to provide goose control programs at the local level.

8.3.18 Permits

Federal and State permits are required to capture, handle, or kill Canada geese, or to disturb their nests or eggs. Permits to kill geese are not issued unless USDA has determined that other measures were not practical or effective. Permits are issued by:

U.S. Fish and Wildlife Service, Permit Office,
P.O. Box 779
Hadley, MA 01035-0779
Phone: (413) 253-8643.

A landowner can chase or disperse geese from his or her property at any time without a permit as long as the birds are not physically harmed. Once a federal permit is issued for any goose control activities, the landowner must also obtain a special permit from DEC. USFWS will send DEC copies of federal permits they issue, so application to DEC is automatic. State permits are issued by:

Special Licenses Unit
NYSDEC, Division of Fish, Wildlife and Marine Resources
625 Broadway
Albany, NY, 12233-4752
Phone: (518) 402-8985.

8.3.19 Plan Ahead

Property owners and communities that have experienced problems in the past can expect geese to return again unless control measures are implemented. The best time to act is in late winter, before nesting begins, or as soon as geese show up where they are not wanted. If any permits are needed, allow plenty of lead time (45-60 days) for processing.

8.3.20 For More Information

If the techniques described in this document are unsuccessful, or if you need more information, contact USDA-Wildlife Services or any DEC regional wildlife office for assistance. USDA can provide information by phone or by mail and will conduct site visits in special problem situations. USDA also can provide control services on site underfunded cooperative agreements (for a fee). For help in New York State, contact:

USDA APHIS - Wildlife Services
1930 Route 9
Castleton, NY 12033-9653
Phone: (518) 477-4837
Fax: (518) 477-4899

DEC also can provide technical advice and information, and refer individuals to licensed nuisance wildlife control specialists or material suppliers who can help. DEC generally does not provide field assistance to individual land owners with goose problems, but will work with local governments to help develop community-based management programs. For assistance, contact the DEC regional office listed in your local telephone directory.

Two excellent reference materials developed by Cornell Cooperative Extension are recommended: ***Suburban Goose Management: Searching for Balance*** (28 minute video); and **Managing Canada Geese in Urban Environments: A Technical Guide** (42 page manual). The video provides a general overview of techniques and issues to help communities begin developing an effective action plan. The manual provides additional details for selecting and implementing various techniques to reduce conflicts with resident geese. To order, contact the Department of Natural Resources, Fernow Hall, Cornell University, Ithaca, NY, phone (607) 255-2115.

9 - Index of Common and Trade Names of Pesticides Registered for Use on Turfgrass

Table 9.1 Plant Growth Regulators Mentioned in this Publication

Trade Name(s)	Common Name	Formulation[1]	EPA Reg. No.
Anuew	prohexadione calcium	WDG	1001-91
*NY Clarelle	paclobutrazol	L	100-1412
Edgeless	flurprimidol, trinexapac-ethyl	L	67690-46
Embark 2-S Plant Growth Regulator	mefluidide	L	2217-759
Embark Turf & Ornamental	mefluidide	L	2217-768
*NY Governor	trinexapac-ethyl	G	9198-245
Musketeer	Flurprimidol, paclobutrazol, trinexapac-ethyl	L	67690-57
*NY Primo Maxx	trinexapac-ethyl	EC	100-937
*NY Proxy	ethephon	L	432-1230
*NY Trimmit	paclobutrazol	SC	100-1014

1 AS = aqueous suspension; DF = dry flowable; DG = dispersible granule; EC = emulsifiable concentrate; F = flowable; G = granular; L = liquid; SC = soluble concentrate

*NY- - Restricted-use pesticide in New York State.

Table 9.2. Fungicides and nematicides Mentioned in this Publication

Trade Name(s)	Common Name	Formulation[1]	EPA Reg. No.
*NY 26GT Fungicide	iprodione	L	432-888
*NY 3336F	thiophanate-methyl	F	1001-69
Aliette WDG Brand Fungicide	fosetyl-al	WDG	432-890
*NY Andersons Golf Products Fertilizer + Fung. VIII	thiophanate-methyl + iprodione	G	9198-228
Anderson's Golf Products 5% Daconil Fungicide	chlorothalonil	G	9198-115
Anderson's Professional Turf Products 1% Bayleton	triadimefon	G	9198-111
*NY Armada	trifloxystrobin + triadimefon	WSP	432-1412
Banol	propamocarb	L	432-942
Compass	trifloxystrobin	DG	432-1371
Concert II	chlorothalonil + propiconazole	L	100-1347
Daconil Action	chlorothalonil +ASM	F	100-1364
Daconil Ultrex Turf Care	chlorothalonil	WDG	50534-202
*NYΔ Eagle 20EW`	myclobutanil	L	62719-463
Emerald	boscalid	EG (WDG)	7969-196
Endorse	polyoxin D zinc salt	W	66330-41
*NY Fore 80WP Rainshield	mancozeb	WP	62719-388
*NY Fungicide X	iprodione	G	9198-210
Heritage	azoxystrobin	DF	100-1093
Heritage TL	azoxystrobin	L	100-1191
Honor Intrinsic Brand Fungicide	pyraclostrobin + boscalid	DF	7969-255
*NY Instrata	fludioxonil + chlorothalonil + propiconazole	F	100-1231

Table 9.2. Fungicides and nematicides Mentioned in this Publication

Trade Name(s)	Common Name	Formulation[1]	EPA Reg. No.
*NY Junction	copper hydroxide + mancozeb	DF	67690-35
Lesco Prodigy Signature	fosetyl-al	EC	432-890-10404
*NY †Lexicon	fluxapyroxad + pyraclostrobin	L	7969-350
*NY †Medallion	fludioxonil	WP	100-769
Pegasus DFX	chlorothalonil	DF	70506-272
ProStar 70WP	flutolanil	70WP	432-1223
Subdue Maxx	metalaxyl (mefenoxam)	EC	100-796
Tartan	trifloxystrobin + triadimefon	L	432-1446
*NY Terrazole	etridiazole	WP	400-416
Tourney	metconazole	WDG	59639-144

[1] AS = aqueous suspension; DF = dry flowable; EC = emulsifiable concentrate; F = flowable; G = granular; L = liquid; SC = soluble concentrate; W or WP = wettable powder; WDG = water-dispersible granule; WSP = water-soluble packet
RR = reduced-risk pesticide. * Federal restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator. *NY restricted use pesticide in New York State.
† Not for use in Nassau and Suffolk Counties Δ Rate and/or other application restrictions apply in New York State. See label for more information.

Table 9.3. Bio-fungicides Mentioned in this Publication

Common Name	Trade Name(s)	Formulation[1]	EPA Reg. No.
Bacillus licheniformis str SB 3086	EcoGuard Biofungicide	EC	70127-2
Bacillus subtillis, strain GB 03	Companion Liquid Biological Fungicide OMRI		71065-3
Bacillus subtilis, strain QST 713	Rhapsody	F	69592-19
Pseudomonas aureofaciens str TX-1	Spot-Less Biofungicide	L	75801-1
Polyoxin D Zinc salt	Endorse	W	66330-41
Mono and di-potassium salts of phosphorus acid	Riverdale Magellan	L	228-387
Trichoderma harzianum Rifai str T-22/ Trichoderma virens str G-41	TurfShield Plus G OMRI	G	68539-10
Trichoderma harzianum Rifai str T-22/ Trichoderma virens str G-41	TurfShieldPlus WP OMRI	WP	68539-9

[1] EC = emulsifiable concentrate; F = flowable; L = liquid; W = wettable powder
OMRI= Certified for use in organic production by Organic Materials Review Institute (OMRI) in 2017

Table 9.4. Insecticides Mentioned in this Publication

Trade Names	Common Name	Formulation[1]	EPA Reg. No.
*NY Acephate 90 WDG	acephate	DG	34704-1051
Amdro Quick Kill Lawn & Landscape Insect Killer Concentrate	zeta-cypermethrin	SC	279-3347-73342
Andersons Golf Products Insecticide III	chlorpyrifos	G	9198-167
*Δ Andersons Golf Products 0.15G Prosect	bifenthrin	G	9198-225
Andersons Prof. Turf Products 8% Granular Insecticide w/Carbaryl	carbaryl	G	9198-146
Δ Andersons Turf Products Duocide Insect Control	bifenthrin + carbaryl	G	9198-235
*NY †[5] Acelepryn	chlorantraniliprole	SC	100-1489
*NY Armortech IMD 75	imidacloprid[4]	WSP	228-588
AzaGuard	azadirachtin	EC	70299-17

Table 9.4. Insecticides Mentioned in this Publication

Trade Names	Common Name	Formulation[1]	EPA Reg. No.
*[NY∆]Bithor SC	bifenthrin + imidacloprid	L	83923-2
Botanigard 22WP	*Beauvaria bassiana*	WP	82074-2
Botanigard ES	*Beauveria bassiana*	EC	82074-1
Conserve SC Turf and Ornamental	spinosad	EC	62719-291
Crymax	*Bacillus thuringiensis,* subsp. *kurstaki*	WDG	70051-86
*[NY]Cyonara 9.7 Insecticide	lambda-cyhalothrin	EC	53883-145
*[NY]Demand EZ Insecticide	lambda-cyhalothrin	EC	100-1232
Dylox 420SL Turf and Ornamental Insecticide	trichlorfon	WSP	432-1464
*[NY]GrubEx Pro	imidacloprid[4]	L	228-485
Howard Johnson's Permethrin	permethrin	G	53883-39-32802
Javelin WG	*Bacillus thuringiensis,* subsp. *kurstaki*	WP	70051-66
*[NY]Merit 2F Insecticide	imidacloprid[4]	F	432-1312
*[NY]Merit 75 WP Insecticide	imidacloprid[4]	WP	432-1314
Ornazin 3% Botanical Insecticide	azadirachtin	EC	5481-476-67690
*Scimitar GC Insecticide	lambda-cyhalothrin	L	100-1088
Sevin SL Carbaryl Insecticide	carbaryl	EC	432-1227
Suspend SC Insecticide	deltamethrin	L	432-763
*Tempo Ultra GC Insecticide	cyfluthrin	L	432-1452

[1] DF = dry flowable; DG = Dispersible granular; EC = emulsifiable concentrate; F = flowable; G = granular; L = liquid; ME = microencapsulated; SC = soluble concentrate; W or WP = wettable powder; WSP = water-soluble packet
[4]All commercial applications of imidacloprid products are restricted-use statewide. In addition, the sale, use and distribution of consumer products are not allowed in Nassau, Suffolk, Kings or Queens Counties. [5] In addition to Long Island (Nassau and Suffolk Counties), product is not for use in Kings and Queens counties. * Federal restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the direct supervision of a certified applicator. *[NY] restricted use pesticide in New York State.
† Not for use in Nassau and Suffolk Counties ∆ Rate and/or other application restrictions apply in New York State. See label for more information.

Table 9.5 Herbicides Mentioned in this Publication

Trade Name(s)	Common Name	Formulation[1]	EPA Reg. No.
Acclaim Extra	fenoxaprop	EC	432-950
Barricade 4FL	prodiamine	EC	100-1139
*[NY]Barricade 65 WG	prodiamine	WG	100-834
Basagran T&O	bentazon	L	7969-326
*[NY]Beacon	primisulfuron-methyl	WDG	100-705 (SLN NY-08-0015)
*[NY]Bensumec 4LF	bensulide	L	2217-696
Chaser 2 Amine	triclopyr + 2,4-D	EC	34704-930
*[NY]†Confront	triclopyr + clopyralid	L	62719-92
Cool Power	MCPA + triclopyr + dicamba	3L	228-317
*[NY]Corral 2.86G	pendimethalin	G	58185-179
*[NY]Dimension Ultra 40WP	dithiopyr	WP	62719-445
*[NY]†Escalade 2	2,4-D +dicamba + fluroxypyr	L	228-442
Fiesta	iron HEDTA	L	67702-26-87865
Gordon's Trimec Ready to Spray Lawn Weed Killer	2,4-D + 2,4-DP + dicamba	L	2217-540
Halts	pendimethalin	G	538-192

Table 9.5 Herbicides Mentioned in this Publication

Trade Name(s)	Common Name	**Formulation**[1]	**EPA Reg. No.**
Lebanon Balan 2.5G	benefin	G	961-268
Lebanon Crabgrass Control 4.6% Tupersan	siduron	G	961-309
Lebanon Proscape Fertilizer with Team Pro .86% Preemergent	benefin + trifluralin	G	62719-289-961
Lebanon Treflan 5G	trifluralin	G	961-405
Lesco Lockup Extra 2 with Fertilizer	2,4-D + dicamba + penoxsulam	G	62719-590-10404
Lesco Pre-M	pendimethalin	EC	241-360-10404
*NY†Lontrel T&O	clopyralid	L	62719-305
*NY†Millennium Ultra 2	2,4-D + clopyralid + dicamba	L	228-332
*NY†Momentum FX2	2,4-D + triclopyr + fluroxypyr	L	228-447-10404
Pendulum	pendimethalin	EC	241-341
Pendulum 2G	pendimethalin	G	241-375
Pendulum Aquacap	pendimethalin	L	241-416
Power Zone	carfentrazone + MCPA + MCPP + dicamba	EC	2217-834
*NYPrograss	ethofumesate	EC	432-941
Pylex	topramezone	L	7969-327
Quicksilver T&O	carfentrazone-ethyl	EC	279-3265
*NYRonstar	oxadiazon	G	432-886
*NY†Riverdale XRM-5202	clopyralid + 2,4-D + triclopyr	L	228-321
Sedgehammer	halosulfuron	DF	81880-1-10163
Speed Zone	carfentrazone + 2,4-D + MCPP + dicamba	L	2217-833
ΔStrike 3	2,4-D + 2,4-DP + fluroxypyr	L	14774-2
*NY†Surge	2,4-D + sulfentrazone + dicamba + MCPP	L	2217-867
*NY†Tailspin	fluroxypyr + triclopyr	L	34704-958
Tenacity	mesotrione	F	100-1267
Trupower 3 Selective	MCPA + clopyralid + dicamba	L	228-551
Tupersan	siduron	WP	10163-213-2217
*NYTurflon II Amine	triclopyr + 2,4-D	EC	228-316
Velocity SG	bispyribac sodium	G	59639-136
Weed Beater	2,4-D + MCPP + dicamba	L	2217-539-4

[1]AS = aqueous suspension; DF = dry flowable; DG = dispersable granule; EC = emulsifiable concentrate; F = flowable; G = granular; L = liquid; SC = soluble concentrate; W or WP = wettable powder; WDG = water-dispersible granule; WSB = water-soluble bag; WSP = water-soluble packet

* Federal restricted-use pesticide; may be purchased and used only by certified applicators or used by someone under the supervision of a certified applicator.

*NY Restricted use pesticide in New York State.

† Not for use in Nassau and Suffolk Counties

Δ Rate and/or other application restrictions apply in New York State. See label for more information.

10 Glossary

Acclimate - To adapt to a new chemical, physical, or biological environment.

Active ingredients - The main inhibitory substance found in a pesticide.

Adsorption - The retention of solids, liquids, or gasses at an interface.

Aestivation - A period of inactivity during the summer months

Biosynthesis - The process by which living cells make molecules, tissues, or organs.

Bulk density- The mass of soil per unit volume.

Cation exchange capacity - The sum total of all exchangeable positively charged ions that a soil can adsorb. Expressed as milliequivalents per gram of soil.

Contact fungicide - Those fungicides that are active only on the external parts of plants.

Degree-day - A measure of how high the average daily temperature is relative to some reference temperature such as the minimum threshold required for insect development to proceed.

Disclosing solution - A liquid irritant that drives certain soil insects to the surface when the soil is drenched, such as a dilute soap or pyrethroid solution.

Disease trading - Increases in severity of non-target diseases following fungicide applications.

EIQ – Environmental Impact Quotient. A method for quantifying the environmental impact of pesticides. See section 1.13

Emulsion - Suspension of liquid droplets within another immiscible liquid.

Endophyte - A group of fungi that live within the plant and produce toxins detrimental to some plant-feeding insects.

Entomopathogenic - Causing disease in insects, such as certain fungi and nematodes.

Environmental Impact Quotient – See "EIQ".

Formulation - All of the ingredients and additives making up a given pesticide product.

Frass – Insect excrement. Its presence and appearance aid in identifying insect problems.

Fungicidal - Treatments that kill fungal pathogens.

Fungistatic - Treatments that prevent fungal pathogens from growing or producing spores or prevent spores from germinating.

Habitat - The area or environment where an organism typically occurs, which provides the food, shelter and other requirements to reproduce and develop.

Half-life - The time required for half of the original amount of applied pesticide to disappear.

Immobilization - The reduction in movement of pesticides.

Inert ingredients - Those components of a formulation that have no pesticidal activity.

Inoculum - The pathogen or parts of the pathogen that can cause infection. Inoculum consists of spores, mycelium, sclerotia, etc.

Instar - The developmental stage of an insect between two successive molts.

Label - All of the written information that accompanies a pesticide. This includes the information affixed to the container as well as any other written material associated with the product.

Larva - The immature stage of an insect between egg and pupa for those groups with complete metamorphosis (egg, larva, pupa, adult), e.g. white grubs.

Leaching - The removal of pesticides dissolved in water from upper soil layers to the ground water.

Localized penetrant - Those fungicides that pass into the tissue underlying the point of application.

Metabolites - Products of microbial metabolism.

Microbial community - Interacting populations of microorganisms.

Mutualistic - A close association between two different species of organisms in which each derives a benefit.

Non-polar molecules - Molecules with no electrical charge.

Nymph - The immature stage of an insect between egg and adult for those groups with incomplete metamorphosis (egg, nymph, adult), e.g. hairy chinch bug.

Penetrant fungicide - Those fungicides that enter plant tissues.

Pheromone - A chemical secreted externally by an insect or other animal to communicate information to members of the same species.

Phloem - Food conducting tissue in a plant that moves sugar from the leaves down to the root system.

Photosynthate - The product of photosynthesis: carbohydrates.

Polar molecules - Molecules possessing two equal and opposite electrical charges.

Prepupa - A non-feeding and relatively inactive stage of an insect after the last larval molt and before the pupa.

Stomata - Pores in the surface of the foliar parts of plants that allow for gas and water exchange. (Stomate = singular).

Systemic penetrant - Those fungicides that pass into the plant tissues and are moved through the xylem and phloem to distant parts of the plant.

Translocation - The transfer and movement of pesticides through the plant.

Transpiration - The loss of water from the surface of leaves.

Vapor pressure - The pressure exerted by a pesticide in its gaseous state in equilibrium with that in the liquid state. A measure of the potential of a pesticide to convert to a gas.

Vascular system - The water and nutrient-conducting tissues of a plant.

Volatilization - The conversion of a pesticide from a liquid to a gaseous state and subsequent escape from soil.

Xylem - Nutrient- and water-conducting tissue in a plant that moves water and nutrients from the root system up to the above-ground portions of the plant.

Tips for Laundering Pesticide-Contaminated Clothing

Prelaundering Information

Remove contaminated clothing **before** entering enclosed tractor cabs.

Remove contaminated clothing **outdoors** or in an entry. If a granular pesticide was used, shake clothing outdoors. **Empty pockets and cuffs.**

Save clothing worn while handling pesticides for that use only. Keep separate from other clothing **before, during, and after** laundering.

Wash contaminated clothing after **each** use. When applying pesticides daily, wash clothing **daily**.

Clean gloves, aprons, boots, rigid hats, respirators, and eyewear by scrubbing with detergent and warm water. Rinse thoroughly and hang in a clean area to dry.

Take these **precautions** when handling contaminated clothing:

- Ventilate area.
- Avoid inhaling steam from washer or dryer.
- Wash hands thoroughly.
- Consider wearing chemical-resistant gloves.
- Keep out of reach of children and pets.

Air

Hang garments outdoors to air.

Prerinse

Use one of three methods:
1. Hose off garments outdoors.
2. Rinse in separate tub or pail.
3. Rinse in automatic washer at full water level.

Pretreat (heavily soiled garments)

Use heavy-duty liquid detergent.

Washer Load

Wash garments separate from family wash.
Wash garments contaminated with the same pesticide together.

Never use the "sudsaver" feature on your machine when laundering pesticide-soiled clothes.

Load Size

Wash only a few garments at once.

Water Level

Use full water level.

Water Temperature

Use **hot** water, as hot as possible.

Wash Cycle

Use **regular** wash cycle, at least 12-minutes.

Laundry Detergent

Use a **heavy-duty** detergent.
Use amount recommended on package or more for heavy soil or hard water.
Remember to use high-efficiency (HE) detergents in HE and front-loading washers.

Rinse

Use a **full** warm rinse.

Rewash

Rewash contaminated garments **two or three times** before reuse for more complete pesticide removal.

Dry

Line drying is preferable, to avoid contaminating dryer.

Clean Washer

Run complete, but empty, cycle.
Use **hot water and detergent.**

Prepared by Charlotte Coffman, College of Human Ecology, Department of Fiber Science and Apparel Design, 607-255-2009

PESTICIDE EMERGENCY NUMBERS

Emergency responder information on pesticide spills and accidents…

CHEMTREC 800-424-9300

For pesticide information…

National Pesticide Information Center 800-858-7378

To Report Oil and Hazardous Material Spills in New York State…

NYS Department of Environmental Conservation
Spill Response .... 800-457-7362 (in NYS)
518-457-7362 (outside NYS)

Poison Control Centers

Poison Control Centers nationwide 800-222-1222

If you are unable to reach a Poison Control Center or obtain the information your doctor needs, the office of the NYS Pesticide Coordinator at Cornell University, 607-255-1866, may be able to assist you in obtaining such information.

This publication is issued to further Cooperative Extension work mandated by acts of Congress of May 8 and June 30, 1914. It was produced with the cooperation of the U.S. Department of Agriculture, Cornell Cooperative Extension, New York State College of Agriculture and Life Sciences, New York State College of Human Ecology, and New York State College of Veterinary Medicine, at Cornell University. Cornell Cooperative Extension provides equal program and employment opportunities. Christopher Watkins, Director.

Produced by:
Cornell Turfgrass Research Program, Cornell University, Plant Science Building, Ithaca, New York 14853-5601. Phone: 607-255-4568. Fax: 607-255-0599. Frank Rossi, Editor in Chief (fsr3@cornell.edu). Jennifer Grant, Editor in Chief (jag7@cornell.edu). Carl Schimenti, Managing Editor (css223@cornell.edu).