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This damage often results in initial yellow areas that grow larger and coalesce into patches of brown or tan turfgrass. The most severe damage often occurs in late summer and early fall and in the same areas each year.

Ongoing projects at North Carolina State University and the University of Florida have been set up to monitor adult activity throughout the year and find the presence of larvae in the turf to gain insight into the hunting billbug's lifecycle in the Southeast. While adult billbugs can be collected in large numbers easily, locating larvae in the field has been next to impossible. The few larvae we found in 2007 were 6 inches below the surface, deeper than the 4 inches previously reported for billbug larvae.

During intense monitoring in North Carolina during 2007, large numbers of adults were present in the fall just prior to and during occurrence of damage. The damage is a result of the large number of adults feeding on the surface during a time of the year when most warm-season grasses are stressed. At this time, larvae are too small to cause damage on this scale, and adults are ravenously feeding to build fat stores for overwintering — or in the case of females, egg production. Only the locations that receive intense feeding result in the "dry patches" during the summer and fall with the majority of damage going unnoticed until the following spring.

During early March 2008, late instar larvae were found in the thatch rather than the soil of dormant zoysiagrass. Traditional knowledge holds that early instars feed in and on the crowns of grass while late instars feed on the root system below the surface. It is assumed these larvae were in the thatch to feed, but this is the first behavior of this kind recorded.

Containment and control

If we are to effectively manage this pest, we need to elucidate more clearly some of this critical information. We need to know which stage causes the damage and have a clear picture of the presence of each life stage. Control of the larval stage can most likely be accomplished with an effective grub insecticide if it is timed properly. Adults can possibly be controlled with a number of the pyrethroid insecticides, such as Talstar, DeltaGard or Scimitar. In the absence of a thorough knowledge of pest biology and ecology, the use of combination products, such as Allectus or Aloft, could cover all the bases. For example, the bifenthrin in Allectus will have activity against the adults, and the imidacloprid should control the larvae. Given our ignorance of pest biology at this time, combinations might be the best insurance treatment available until our knowledge base improves.

It has long been known that effective control of white grubs and mole crickets requires knowledge of pest biology, a means to monitor activity and timely applications of the best product(s) for control. The same is true for the hunting billbug. This knowledge will be gained through comprehensive field and laboratory studies that outline its lifecycle and behavior in the warm-season turfgrass areas.

In the coming years, we will continue to monitor adult activity with linear pitfall traps, not only in warm-season grasses, but expand to include cool-season grasses such as fescue and bluegrass. Greenhouse studies are being conducted using field-collected adult billbugs to gain a clearer understanding of lifecycle length and potential generations per year. Laboratory studies will provide new information on the damaging stages and adult behavior. In addition, studies tracking the movement and location of adults on the surface, in the thatch and in the soil before, during, and after overwintering will be conducted using innovative tracking methods. As our knowledge of this pest increases, our ability to manage it and prevent the damage that we are seeing more frequently on bermudagrass and zoysiagrass will also improve.

Dr. Rick Brandenburg is the co-director of the Center for Turfgrass Environmental Research and Education and at North Carolina State University. Jake Doskocil is a research assistant in the entomology department. He is working toward his Ph.D. on the biology and ecology of the hunting billbug.

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Gene Flow in Genetically Altered Crops Helps Progress Transgenic Turfgrass

By David Gealy

Genetic improvement of plants through the introduction of a variety of traits — such as tolerance to insects, disease, chemicals, drought or fewer nutrients — is common in agriculture throughout the world. Traditional approaches, such as classical breeding, induced mutagenesis or wide crossing, have a long track record of success. Transgenic technologies, in which genes conferring useful traits of interest are transferred between different species, have been used for genetic improvement for little more than a decade.

Gene flow is the successful transfer of genetic information between different individuals, populations and generations (to progeny) and across spatial dimensions. It is common in nature and maintains the biological diversity that helps ensure long-term survival of populations and species in variable environments. Typically initiated by pollen dispersal in plants, gene flow is a natural and not inherently adverse phenomenon that occurs in non-transgenic as well as transgenic plants and crops.

Gene flow potential in plants is largely determined by reproductive biology (Table 1, p. 54). In some species, flowers attract pollinators such as insects or pollen grains are able to travel long distances by wind. In other species, gene flow potential is restricted because their flowers self-fertilize before pollen dispersal. Thus, the reproductive biology of crops largely governs the frequency of outcrossing. Crop reproductive biology can range from almost exclusively self-pollinating to 100 percent outcrossing. Outcrossing frequency typically decreases with distance between the pollen-producing plant and the recipient plant and with the time period between pollen dispersal and fertilization on the recipient plant. Gene flow potential tends to be higher in crop species that have high natural levels of outcrossing. Pollen dispersal, however, leads to true gene flow only if the dispersed pollen fertilizes flowers leading to seed formation and seeds that germinate to produce plants that are competitive enough to reproduce over time. Traits such as herbicide resistance can impart a sizeable selective advantage in locations where the herbicide is used. Under this scenario, there is likely to be a greater degree of gene flow success following the initial pollen dispersal and outcrossing event than in locations where the herbicide is not used.

Physical movement of genetic traits via seeds — such as shattering, wind, water or distribution by animals — or vegetative propagules, including rhizomes and stolons, are not considered true gene flow, but it can be economically important depending on the transgenic crop and production practices. Typically, seed traits such as shattering or movement with air currents that encourage dispersal are not found in most domesticated crops. A number of turfgrasses are propagated by stolons or rhizomes.

Corn, soybean, canola and cotton represent about 99 percent of all commercialized transgenic crop production worldwide. Seed dispersal occurs at a minimal level in all these crops. Outcrossing is limited in soybean, wheat and rice. Canola and corn have greater outcrossing.

The United States also grows transgenic papaya, squash and alfalfa commercially. Transgenics have been produced in other crops/species, but few are presently proceeding through the regulatory process toward commercialization. These include turfgrasses as well as grain crops, vegetables, fruits, ornamental plants, forage crops and trees. Additional species granted nonregulated status or in the process of deregulation or approval include creeping bentgrass, carnation, tobacco, tomato, plum, potato, beet and sugar beet.

Gene flow in a larger context

Gene flow is only one of several mechanisms by which plants or seeds become intermixed at low levels with other plants or seeds where humans did not intend them to be. This type of unintended mixing occurs with both transgenic and nontransgenic plants and crops. Other mechanisms include inadvertent physical dispersal or mixing of seed, quality-control failures and inevitable human mistakes. Low or trace levels of commingling via all of these mechanisms is virtually unavoidable in

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TABLE 1

Examples of useful traits being imparted to plants using all available approaches, and estimates of the probable consequences from gene flow[1]

New characteristics being imparted to crop plants[1]			
Potential grower/agricultural problems			
Potential nonagricultural/human safety problems			
	Potential for natural selection process to transform crop into unmanageable "weed" or "volunteer"[2]	Potential for natural selection process to worsen existing problem or create new agronomic problems resulting from gene flow to wild/compatible relative[2]	Potential that off-site gene flow would create significant adverse human health/nutrition impact [2]
•Herbicide tolerance	med[3]	low-med[3]	neg[3]
•Insect tolerance	low-med	med	neg
•Disease tolerance (fungal, bacterial, viral)	low-med	med	neg
•Nematode tolerance	low-med	low-med	neg
•Salt tolerance	low-med	low-med	neg
•Drought tolerance	low-med	med	neg
•Cold/freezing tolerance	low-med	low-med	neg
•Improved nitrogen use efficiency	low	low-med	neg
•Early season vigor	low	low-med	neg
•Increased growth rate	low	low-med	neg
•Reduced plant height	low	low	neg
•Seed shattering resistance	neg	neg	neg
•Altered flowering time	low	low	neg
•Male sterility in crop plant	neg	neg	neg
•Yield/yield components	neg	neg	neg
•Altered maturity date	low	low	neg
•Altered fruit shape/flavor	neg	neg	neg
•Seed protein or oil content or quality	neg	neg	low-med
•Plant-made pharmaceuticals (PMPs) (many traits)	neg	neg	med-high
•Industrial compounds	neg	neg	med-high

1. Approaches include transgenic as well as traditional, nontransgenic classical breeding approaches that use long-established methods to introduce and select for desirable traits in crops. All traits are eventually manipulated through classical breeding methods before commercialization.

2. Estimates compare the most probable outcomes relating to gene flow. Outcomes of gene flow listed here may differ among transgenic crops; some crop/weed species combinations are more likely than others to have high outcrossing or gene flow; and some weed species are inherently more aggressive than others.

3. Key for degree of problem expected (author estimates). Negligible, "neg"; low, "low"; medium, "med"; high, "high." The degree of the problem is likely to vary for a given characteristic or trait depending on the reproductive biology of the species, the trait itself and the cropping system in which it is used.

Source: Council for Agriculture Science and Technology

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QUICK TIP

Summertime is barbecue season, and hopefully we're talking ribs and hamburgers and not ultra-tanned bodies. Also true to summer and hot weather is increased insect activity. One common aspect insects and fertilizers have with turfgrass is the importance of best management practices. BMP's are innovative, dynamic and improved environmental protection practices applied to proper turfgrass management. A good example would be the application of both fertilizers and insecticides in the proper timing to reach the intended result with reduced impact to the environment. Of course, other factors are important as well, such as product selection; so make the right choice, and stay cool.

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commercial-scale plant production. Thus, requirements for unrealistically low occurrence of unwanted substances, such as transgenic seed, can lead to progressively higher overall costs to industry and consumers without a measurable benefit.

Gene flow from transgenic crop plants to weedy or wild relatives can be an issue if they are sexually compatible. Thus, one way to view gene flow issues in a global context is from the perspective of the important worldwide food/feed crops and the weedy or wild species with which they are sexually compatible. About 200 plant species account for essentially all of the significant economic activities for humans worldwide, and approximately 10 percent of these account for almost all of the human caloric consumption. Among the world's worst weed species, only five groups — related weeds of rice, sorghum, rapeseed, sugarcane and oats — are sexually compatible with the most important crops. The potential for gene flow between crop and weed species might not become actual gene flow due to differing habitats or geographic distribution, genetic barriers to outcrossing, etc. The number of combinations of transgenic crop/weed or transgenic crop/nontransgenic crop that are likely to develop highly troublesome gene flow problems is quite small globally. Problems with particular weed or crop species, however, could occur locally or regionally for certain traits conferred by transgenes.

The biology of the transgene trait will largely determine consequences of gene flow to sexually compatible nontransgenic crops, weeds and wild relatives. Outcrossing from herbicide-tolerant transgenic crops can produce progeny that is highly favored in areas where the particular herbicide is used, but not in other areas. However, ordinary selection pressure from repeated herbicide use in herbicide-resistant crops may lead to a greater development of weed resistance (in the absence of gene flow) than gene selections attributable to gene flow between the crop and weed.

Importation of weeds or other plants from foreign lands is an historic problem, but instances in which fully domesticated crops have become weed nuisances are rare. The chances that transgenic modification of a single trait in a domesticated crop would change the crop into a successful weed also is low, and gene flow from the majority of transgenic crops probably will have minimal ecological impacts outside of agricultural areas.

Transgenes that confer tolerance to stresses — such as drought, diseases, insects and salty soil — might require different or additional evaluation because gene flow into nontransgenic crops or weedy relatives can provide selective advantages in both agricultural and nonagricultural settings.

Risk assessment for transgenic crops

Before transgenic crops are approved for commercial use, law requires that they pass extensive testing addressing any significant food safety, environmental protection and human/animal health issues. Once approved, concerns about low-level presence of transgenes from gene flow or other mechanisms mostly revolve around economic issues, such as contract specifications and consumer expectations.

Risk assessment is an early step in the approval process for transgenic crops. Risk is the possibility of harm occurring. For a risk to be realized, there must be something harmful or adverse and also a likelihood that it will occur. Hazards do not pose risks unless there is significant exposure. Likewise, significant exposure does not constitute a risk if it poses a very low hazard. Gene flow fits the exposure part of the risk equation. Risk assessments of transgenic crops in the United States use accepted scientific methods and analyses. They are case by case; conclusions are examined in light of new and established information, and they are comparative, using the nontransgenic crop or plant as the basis for characterizing risk. The vast majority of gene flow events between transgenic crops possessing a wide array of transgenic traits and nontransgenic crops or weeds likely will not lead to a hazard. The transgenic crops approved for commercial

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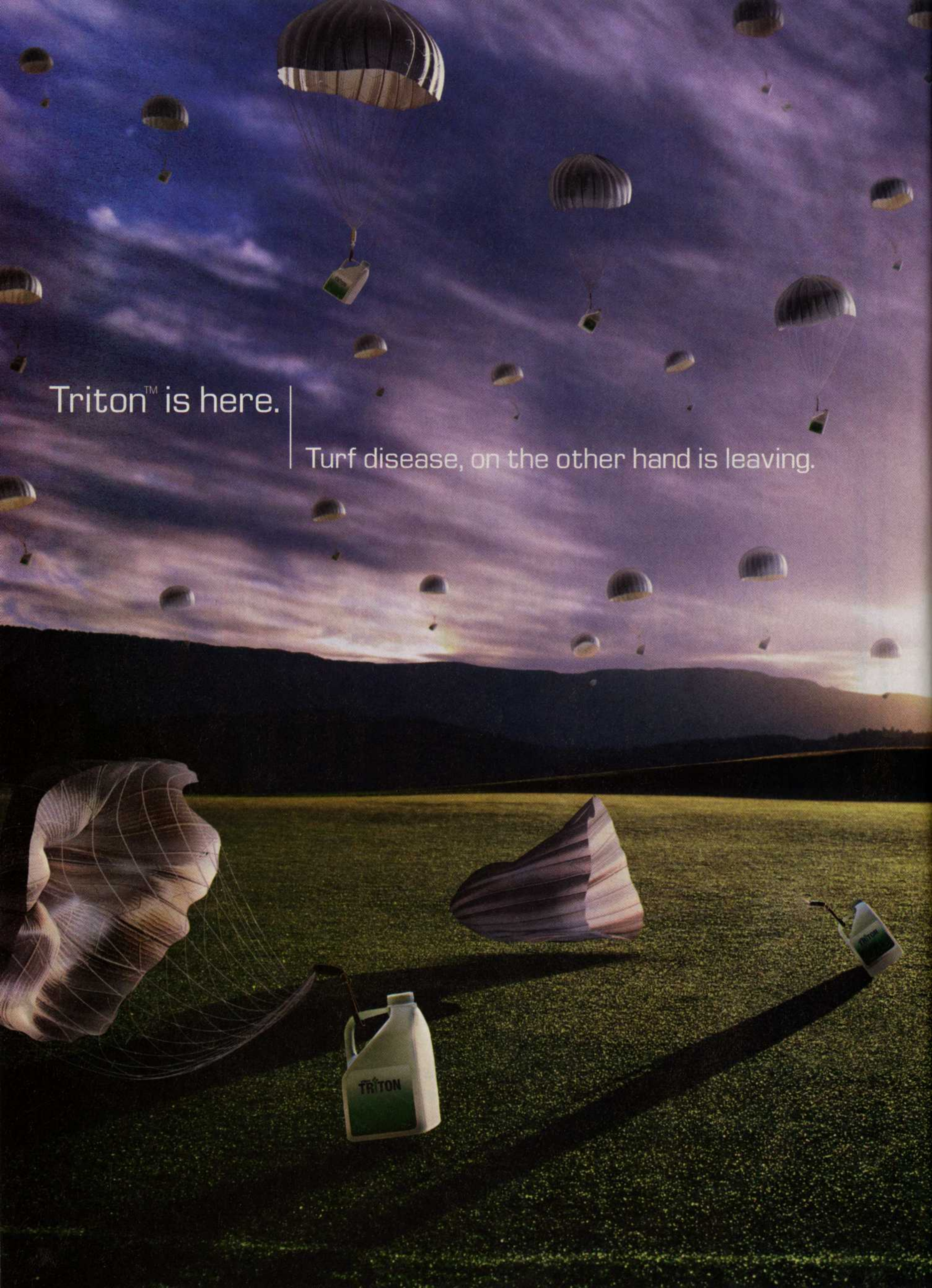
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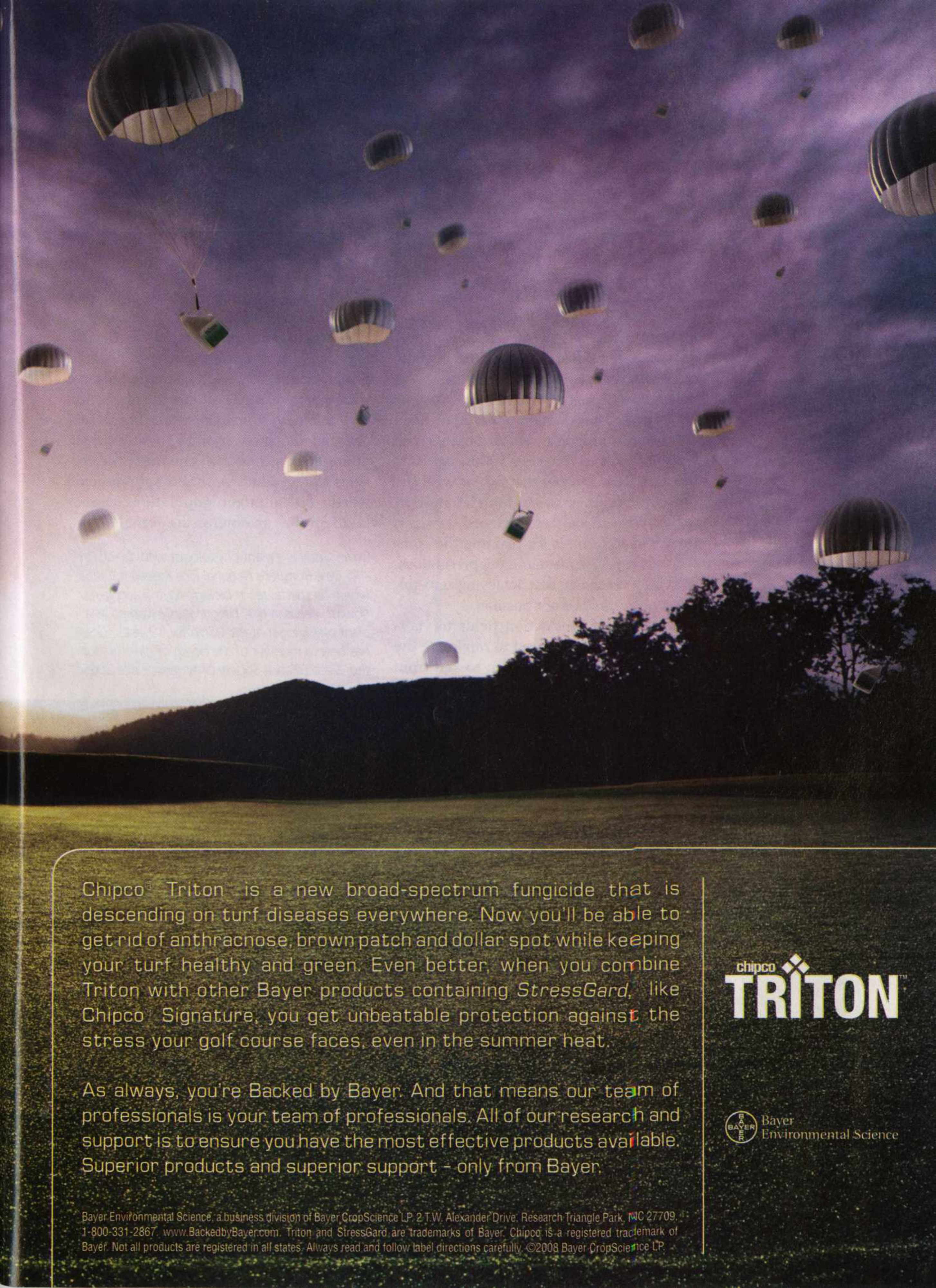
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use in the United States to date have been shown to pose no or minimal risk to health and the environment.

Developing uniform seeds for planting is a major economic concern for producers and suppliers of transgenic and nontransgenic seed. For many decades, procedures for maintaining genetic integrity in seed production have been in place for nontransgenic crops, but some amount of admixture — via pollen flow or mechanical mixing — occurs with all seed-production operations. Seed certification programs, which began in the United States in the early 1900s, typically use a pedigree system that begins with the breeder and progresses to foundation seed, registered seed and certified seed, which is then sold to farmers for planting the commercial crop. Despite numerous precautions, seed laws recognize that achieving zero-tolerance thresholds is not possible.

Isolation of production fields to varying degrees has been used to minimize the inflow and outflow of pollen to and from these fields. This principle can be used with seed production fields, transgenic crops or both. Although this practice can restrict pollen flow substantially, it cannot assure zero gene flow on a landscape level. Novel molecular approaches to further prevent unwanted transfer or spread of transgenes are being developed and could be implemented where warranted. Among these are: 1) insertion of transgenes into organelles — such as chloroplasts — that do not pass along their genes through pollen; 2) adding a male sterility trait that prevents seed production in crop/weed plants that receive transgenic pollen; 3) genetic use restriction technologies, which cause sterility in second-generation seeds; and 4) tightly linking desired transgenes to a gene that is deleterious to reproductive fitness so transgenic weedy or volunteer populations cannot build up after an outcrossing event.

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TURFGRASS TRENDS

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