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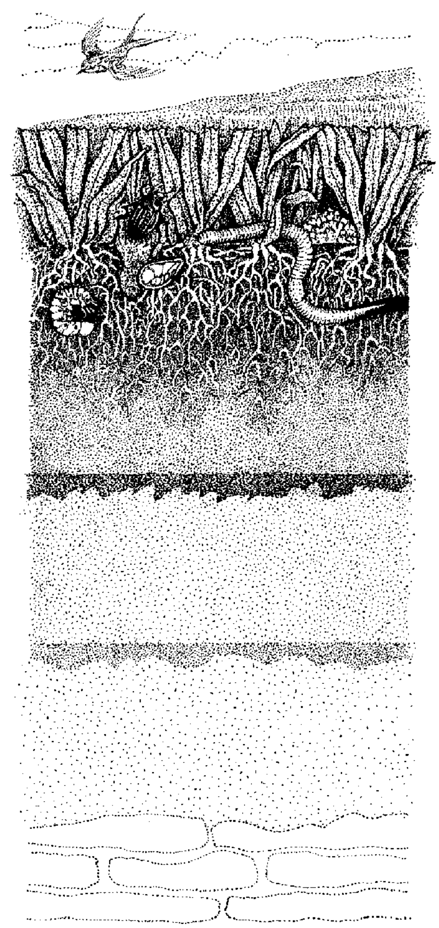

Developing Natural Pest Control Products for Turf

Biorational alternatives for pest control are gaining increased attention worldwide because of concerns related to pesticide usage and the environment, as well as the dwindling number of labeled products, particularly for minor-use crops such as turf and ornamentals. As a result, the science of allelopathy offers interesting alternative weed control strategies through the production and release of natural chemicals from living or decomposing plant materials. ■

The term allelopathy was first introduced in 1937 and refers to biochemical interactions among plants that alters plant growth, including those mediated by microorganisms. Allelopathy, besides including competition for resources among plants, is considered to be an important mechanism of plant interference caused by the addition of plant-produced toxins to the plant environment. Chemicals with allelopathic activity are present in virtually all plants and in most tissues, including leaves, stems, flowers, roots, seeds, and buds. Under appropriate conditions, these chemicals may be released into the environment, generally in the rhizosphere region directly around developing plant roots, in quantities sufficient to affect the growth of neighboring plants. In many cases, allelopathic interactions in the field are difficult to study, since reduction in plant growth can also be caused by competition from surrounding plants for light, nutrients, and water as well as CO_2. These interference mechanisms are often impossible to separate in field studies, but are well documented under controlled conditions in the laboratory or greenhouse.

Black Walnuts

One example of a commonly observed allelopathic interaction can be seen across New York State in homeowners' yards, golf courses and woodlands (see Figure 1). The black walnut tree, *Juglans nigra*, has been reported for centuries to inhibit plant growth through the production of a potent natural herbicide or allelochemical, juglone. Juglone is a chemical compound produced in the bark and living root system of black walnut trees.

Juglone can persist in the soil for several months after removal of a black walnut tree, and causes severe reductions in plant growth to sensitive neighboring species, such as azaleas. Juglone alters plant growth directly through specific metabolic inhibition. Sensitive species include many vegetables crops, woody ornamental shrubs and herbaceous groundcovers. The Ericaceous species, including rhododendrons and azaleas are particularly affected by living black walnuts which release juglone. You may also be familiar with tomatoes which quickly wilt when

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Natural Pest Control

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Examples of weeds which are known to be strongly allelopathic include quackgrass* (Agropyron repens) *and black mustard* (Brassica nigra), *among others. Many of these plants will be found in almost pure stands or monocultures, indicating that other plants have difficulty competing successfully with them once they become established.

planted around black walnuts, hence the term "walnut wilt" which describes the appearance of sensitive plants. Yet, not all plants are sensitive to juglone, just as not all herbicides control every plant. For example, hollies, hydrangeas and daylilies are quite tolerant to black walnut's presence as I have recently observed, as well as hemlock and a variety of hostas and spring flowering bulbs.

The effect of juglone is similar to that of a persistent soil-applied herbicide and can be seen even after the walnut is removed from the growing site, giving plant growth suppression for several months after removal. In this case, up to 3 or 4 months are required after tree removal before the growth inhibition is minimized. While black walnut's allelopathic interactions have been well documented over the years, there are many other suppressive interactions occurring in nature, most of which remain largely uninvestigated.

Allelopathy All Around

During the past 30 years, the potential impacts of allelopathy have been described for certain agronomic crops and cropping systems. Much work has focused on the detrimental effects of living plants or their residues on the growth of crop plants and reductions on crop yields. Replanting problems, autotoxicity, toxicity of mulch stubble, problems with crop rotations, and direct interference by certain weeds have been attributed to allelopathy and allelopathic interactions. Examples of weeds which are known to be strongly allelopathic include quackgrass (*Agropyron repens*) and black mustard (*Brassica nigra*), among others. Many of these plants will be found in almost pure stands or monocultures, indicating that other plants have difficulty competing successfully with them once they become established.

Quackgrass can be observed throughout the Northeastern U.S. on and off the golf course and in landscapes. In pure stands, it inhibits the growth of many surrounding weeds and crops, particularly legume crops such as clovers, beans and peas. Living and decomposing residues release water-soluble toxins which are particularly inhibitory. In fact, the presence of these water-soluble toxins in the field and in the laboratory so strongly inhibited legume root growth, that root hair formation was limited and as a result, nodulation and nitrogen fixation were severely reduced. Interference resulted in the markedly chlorotic and stunted appearance of legume crops grown in the presence of dense quackgrass infestations observed in Michigan and throughout the Northeast.

Black mustard is a common weed which often invades the grasslands of coastal California and other areas in the Northeastern U.S. and forms pure stands over time. In areas adjacent to mustard infestations, grass seeds do not germinate and seedling grass populations never emerge, despite optimal water supplies and high densities of grass seeds. Nearby, one will find dense stands of various annual grasses, but never beneath black mustard stands. Large quantities of sulfur-containing compounds were found to be produced when mustard vegetation is crushed. In addition, water soluble compounds were leached from dead leaves and stems of mustard and were found to be very inhibitory to grass germination. One can observe other densely planted stands of cultivated Brassica species with relatively few if any grass weeds.

Another interesting weed which is invasive in nature and a serious problem in New York's nurseries and landscapes is mugwort (*Artemisia vulgaris*). This perennial weed reproduces by underground rootstocks and spreads easily with cultivation throughout a field site. Once established, it forms dense stands, often with few other weeds. Nurseries in Western New York have referred to mugwort as their worst pest control problem, due to its invasive nature. In appearance, it resembles chrysanthemum and is sometimes referred to as chrysanthemum weed.

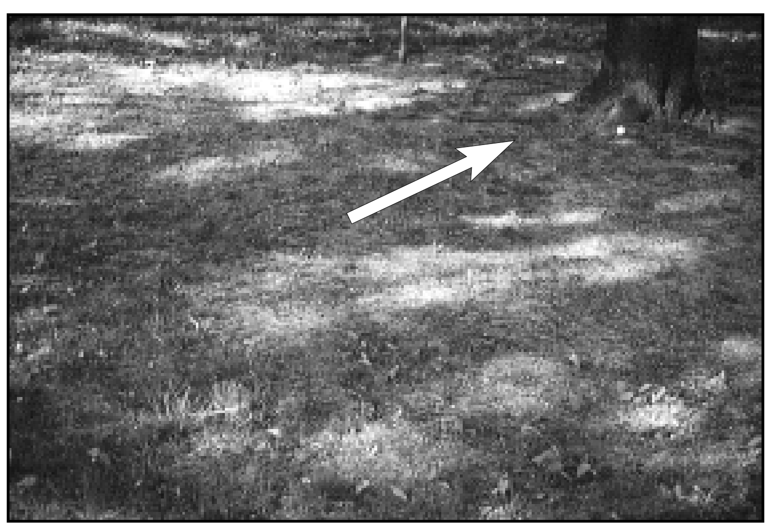

Figure 1. *The lack of plants around the base of this walnut tree is an example of allelopathy.*

One can easily find this weed in landscape settings, fallow fields and even the rough surrounding the golf course.

The genus *Artemisia* includes the wormwoods, sagebrushes, the mugworts, the sageworts, and tarragon. This genus has been the source of folk medicines, spices, flavorings, and insect repellents throughout history. All of the *Artemisia* species produce a diversity of chemical compounds. The function of these chemicals is almost certainly protective, forming a barrier to insect and pathogen attack.

Numerous compounds from *Artemisia* species are also very active as plant growth inhibitors. In fact, two commercial herbicides were developed based on the *Artemsia* chemistries. The herbicide Cinch or cinmethylin is utilized in Europe for weed management. It acts by inhibiting cell division in sensitive plants. We are currently evaluating the allelopathic potential of mugwort in an attempt to understand its biology and develop more effective postemergence control strategies for this difficult-to-control weed.

Synthesizing Natural Products

Researchers first explored the possibility of utilizing allelopathic crops to dominate or inhibit weed growth in agricultural sites in 1974. Why not utilize an allelopathic cover crop or row crop to suppress weeds throughout the growing season? This area has recently received increased attention as crops and cultivars are now being selected for enhanced allelopathic or weed suppressive activity and breeding programs are starting to select for these useful traits. In addition, the diversity of allelochemics produced by higher plants as well as microorganisms is vast.

Recently the chemical industry has spent much time and effort identifying novel secondary products isolated from plants and microorganisms as these compounds may have medicinal or pharmaceutical value as well as pesticidal value. Many of these compounds do exhibit herbicidal activity and consequently, interest exists in using these natural products as models for synthetic herbicides. In many cases, natural products offer novel modes of action for herbicides and other pesticides. With resistance to pesticides causing numerous problems for producers, the development of novel products with completely different modes of action makes natural product screening of increasing importance to the chemical and pharmaceutical industry.

Natural product screening has paid off for DowAgroScience, who recently developed an entire line of environmentally sound insecticides from microbially produced natural products, Spinosad A and Spinosad D. Because of the relative safety and selectivity of Spinosad, new product lines are currently being introduced in turf and ornamentals, the first being called Conserve. Because of the structural complexity of the Spinosads, this product is produced only by microbial fermentation of the fungus *Saccharopolyspora spinosa*. Numerous other smaller biotech firms are also evaluating plant-produced and microbially-produced products for development since these products are able to be fast-tracked through the EPA registration process.

Figure 2. *Debris from killed turfgrasses can have weed suppressive properties.*

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Cover Crops for Landscape

Rotational or green manure crops that provide weed suppression can be an effective cultural means to control weeds with minimal applications of pesticides. In areas to be established as nurseries or landscape sites not under current production, one can easily establish a cover crop or smother crop to eliminate specific weeds or reduce weed populations. Smother crops such as winter rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.), buckwheat (*Fagopyrum esculentum*), black mustard, or sorghum-sudangrass hybrids (*Sorghum bicolor x Sorghum sudanese*) can be very effective in reducing weed populations (see Figure 2).

Many of these crops can be quickly established the season before turf, nursery sites or landscape beds are established. The crops suppress weeds through a combination of competition and allelochemicals produced by the decomposing crop, once it is turned under or killed. These crops could be effectively used in areas bordering a course or field, which is currently not in production, to minimize surrounding weed populations and prevent weed seed dispersal into production sites. For example, sorghum sudangrass has been used throughout the U.S. by nursery producers before planting ornamental crops. A dense stand is established, allowed to grow for about 6 to 8 weeks, and then turned

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Natural Pest Control

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under as a green manure. This adds organic matter to the site over time, and contributes to weed reductions the following season. The year following sorghum establishment, over 70% reductions in small seeded broadleaf weeds have been observed compared to areas receiving normal tillage or other cover treatments.

"Don" Sorgoleone

We are currently looking at sorghum species which produce large quantities of sorgoleone, exuded directly by the living root systems. This compound is an extremely potent inhibitor of photosynthesis and is more active at the site of action than commercial herbicides such as atrazine. Over time, sorgoleone is released into the soil rhizosphere, where it persists for up to several weeks at concentrations capable of suppressing small seeded grasses and broadleafs.

Our laboratory is currently focusing on ways to enhance sorgoleone production in sorghum species to more effectively utilize this cover crop for long term weed suppression in horticultural cropping systems. We are currently attempting to isolate and identify the genes responsible for production, so this trait might be introduced into other crops such where chemical and cultural practices for weed management are less effective.

Figure 3. *Current NTEP trials being evaluated for weed suppressiveness.*

What About Turf?

Turfgrasses also show promise as weed suppressive crops with apparent allelopathic potential. Fescues—especially creeping red fescue and chewings fescue, and tall fescue—have been reported to be both allelopathic and weed suppressive. In research from Kentucky, creeping red fescue was slow growing with less biomass accumulation than other cover crops, but was most highly weed suppressive when living and up to 8 weeks after kill. Not only did red fescue have up to 95% fewer weeds than other cover crop treatments, it also inhibited later establishment of no-till crops, indicating some persistent suppressive properties. Fescues have also interfered with the growth of seedling trees and perennial legume species. Recently, while observing the NTEP Fine Fescue Trial at the Cornell Turfgrass Research Center, it was clear that certain creeping and chewings fescue cultivars were exceptionally weed suppressive while others allowed invasive species to take hold (see Figure 3). The turf density alone was not responsible for enhanced suppression, since less dense, fine leaf cultivars were also weed free. It is likely that suppression is associated with the production of allelochemicals by *Festuca* species.

Extracts of fescue shoots have also been shown to be phytotoxic to seedling germination. In past experiments, we have shown that red fescue extracts were highly suppressive to weed seed germination and growth. These extracts contained various compounds, several of which were markedly active as inhibitors. Our studies with cover crop establishment also showed that perennial ryegrass was quite weed suppressive as well, with up to 85% reduction in weed populations in the residue. Our current challenge is to develop screening procedures to accurately predict which turfgrass cultivars interfere most with weed establishment at the seedling stage of growth and also as a well established, mature turf stand. In this way, we can evaluate allelochemicals produced by active turfgrasses, determine how they act to inhibit plant growth and try to discover genetically and environmentally how suppressiveness is regulated.

The Future

Crop germplasm serves as a source of material to screen in an attempt to enhance weed suppression in crop plants through conventional or nontraditional breeding programs for enhancement of the crop itself. Current evaluation for weed suppression is occurring in turfgrasses, rice, rye, sorghums, and sunflowers.

Allelopathic crops and weeds offer exciting new opportunities for the development of bioactive herbicides, pesticides and pharmaceuticals. The chemical industry is very interested in novel natural products which can be used as templates for pesticide development. Most recently, Zeneca discovered a new family of herbicidal compounds with a completely novel mode of action by working with extracts of the Australian bottlebrush plant. With all this attention, the turf and ornamentals industry will soon see a variety of new herbicides, fungicides and insecticides that are naturally produced or developed from natural products.

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