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Developing Turfgrasses With Enhanced Insect Resistance

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Great strides have been made in the development of improved turfgrasses. Turfgrass managers can now choose among many species and select an adapted cultivar with an attractive appearance, improved stress tolerance and resistance to some diseases. Improvements have also been made in resistance to insect pests, especially endophyte-enhanced resistance. This article will discuss how insect-resistant cultivars are developed and how turfgrass managers can use them.

How Insect-Resistant Cultivars are Developed

Turfgrass breeding is a young discipline with initial efforts focused primarily on improving quality. Now the emphasis has shifted towards stress tolerance, decreased maintenance needs, and improved disease and insect resistance. How does a plant breeder make these improvements to a grass cultivar? A number of methods are used, depending upon the grass species.

All breeding projects start with an extensive collection of plant material. If the goal is improving the summer stress tolerance of bentgrass, for example, then the breeder collects plants from old turfs that have been subjected to severe summer stress. This germplasm collection is then evaluated in turf plots and/or placed in crossing blocks. Seed is harvested from promising plants and the offspring are evaluated under summer stress. This cycle would be repeated for many generations until a population is developed which exhibits improved summer stress tolerance and good turf performance. This method,

Three Types of Insect Resistance

1) antixenosis (nonpreference)
2) antibiosis
3) tolerance

IN THIS ISSUE

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called recurrent selection, has been successfully used to develop many new fescue, ryegrass, and now bentgrass cultivars.

Kentucky bluegrass, on the other hand, reproduces through apomixis, where seeds are produced asexually and offspring are genetically identical to the maternal parent. Because of apomixis, one superior plant can become a new cultivar, but production of hybrids and improvements are more difficult. With the warm-season grasses, superior clones are selected and then vegetatively reproduced. In recent years, projects to develop seeded cultivars of warm-season turfgrasses have also been initiated.

To develop a grass with insect resistance much the same methods would be used. Relatively few breeding projects, however, have had the specific goal of improving insect resistance. Instead, when natural insect infestations occur in cultivar evaluation trials, the trials are rated for insect damage. Cultivars that consistently show less damage are considered to have enhanced resistance to that pest.

Tables 1 and 2 list grasses and insect pests where differences in genetic resistance have been found. Each of these cases represents an opportunity to further improve resistance to turfgrass pests. In the warm-season grasses, no endophytic fungi have been discovered, so the resistance is due to the genetics of the grass plant. The cool-season grasses, on the other hand, have both genetic and endophyte-enhanced resistance. Table 2 shows examples of insect resistance due to the presence of endophytic fungi in the grass plant.

Working with insects presents a unique set of challenges to the turfgrass breeder. In our earlier example of improving summer stress tolerance, it was relatively easy to subject test plots to summer stress. However, natural insect infestations are unpredictable and unevenly distributed, making screening for resistance in the field difficult. Screening trials in caged plots, potted plants or laboratory dishes are used to help determine the insect resistance of grass selections. But each of these methods has its drawbacks. Insects must either be collected or reared, although with many insects there are no reliable rearing methods. Laboratory trials often do a poor job of simulating conditions in the field and results are sometimes misleading.

Once a grass is identified as having resistance to an insect, it can be used in developing a new cultivar. Thus, improvements can be made without understanding the mechanism of resistance.

However, because insects are difficult to work with it, it can be useful to learn what is causing the resistance. For example, we don't need to know why a chinch bug avoids a fescue plant in order to take advantage of that avoidance. But if we did know why, we could select plants with that characteristic and make improvements without having to work with the chinch bug. This is the case with endophyte-enhanced resistance, breeders can screen plants for the presence of endophytic fungi.

Scientists have classified three mechanisms, or types, of resistance: 1) antixenosis (or nonpreference) - the plant is not a suitable host; examples in grass include leaf blade being too narrow, plant color, or tough tissue; 2) antibiosis - the plant adversely affects the biology of the insect; such as poor digestibility, or the toxins associated with endophytes; and 3) tolerance - the plant can tolerate insect feeding without showing damage; usually due

Table 1. Examples of turfgrasses where differences in genetic resistance to insect pests have been found.

Warm-Season Grasses

Zoysiagrass -- tropical sod webworm, fall armyworm, Banks grass mite, zoysiagrass mite

St. Augustinegrass -- southern chinch bug, tropical sod webworm, Rhodesgrass mealybug

Bermudagrass -- tropical sod webworm, fall armyworm, southern and tawny mole crickets, bermudagrass scale, stunt mite, spittlebug

Buffalograss -- mealybug, eriophyid mite, chinch bug

Bahiagrass -- mole cricket

Cool-Season Grasses

Kentucky bluegrass -- billbug, hairy chinch bug, sod webworm, greenbug

Perennial ryegrass -- billbug, hairy chinch bug

Fescues -- hairy chinch bug

Creeping bentgrass -- sod webworm

to aggressiveness and ability to outgrow damage. Tolerance and endophyte-enhanced resistance are probably the most common mechanisms of resistance in turfgrass.

Genetic Insect Resistance

Turfgrass managers can select cultivars with either genetic or endophyte-enhanced resistance to insect pests. Following are a few examples of genetic resistance to insects.

Kentucky bluegrass and billbugs: The differences in susceptibility to billbugs among Kentucky bluegrass cultivars have been studied for a number of years. The larvae of several billbug species can do extensive damage to bluegrass, feeding on the crown and roots in mid to late summer. Studies in New Jersey and Nebraska have suggested a number of mechanisms of resistance, including females avoiding narrow-leafed cultivars for egglaying, tougher leaf tissue, and aggressive cultivars outgrowing damage. Recent trials suggest an association between resistance and heat and drought tolerance. As we learn more about this resistance it should be possible to make further improvements. In areas where billbugs are a problem, one of the resistant cultivars listed in Table 3 should be included in the seed mixture.

St. Augustinegrass and Southern chinch bugs: The Southern chinch bug does such extensive damage to St. Augustinegrass that a breeding project was initiated in Florida to identify resistant plants. In 1973, 'Floratam' was released as a resistant St. Augustinegrass and was widely planted in southern Florida. Laboratory studies showed that chinch bugs had reduced survival on resistant plants, indicating antibiosis. Unfortunately, a population of chinch bugs gradually developed that were able to survive on Floratam. A new cultivar, named FX10, has now been developed that is resistant to these chinch bugs.

Buffalograss and mealybugs: Buffalograss is a good example of a new turfgrass species that is filling a special niche of a low maintenance grass. Mealybugs, however, can cause severe damage to buffalograss. Differences in susceptibility had been observed in the field, so for my graduate work at the University of Nebraska, I chose to study this association. Many plant selections were screened by spreading infected clippings over potted plants and evaluating severity of infestation. Cultivars '609' and 'Prairie' were highly resistant and the resistance appeared to be correlated with a lack of leaf pubescence. We hypothesized that the pubescence provides a framework within which eggs are laid, or a foothold for young mealybugs. It may also catch a hold of wind-borne mealybugs, or hinder the movement of a parasitic wasp which attacks mealybugs. Unfortunately, northern adapted cultivars '315' and '378' are moderately susceptible.

Kentucky bluegrass and white grubs: Recent findings at Rutgers University show that Kentucky bluegrass cultivars vary significantly in their summer stress tolerance. Root mass measurements were taken before and after a period of summer stress from two groups of cultivars, one group that generally shows good summer stress tolerance, and one that shows poor stress tolerance. Before the stress period, no difference in root mass was found. However, after the stress the group with summer stress tolerance had a higher root mass than the intolerant group. The ability to continue producing roots under summer stress is probably very important to tolerating grub feeding. The cultivars with better summer stress tolerance were the Mid-Atlantic and Mid-West (or Common) types of Kentucky bluegrass (see Table 4). When grub damage was evaluated in another trial, the Mid-Atlantic types generally showed the least damage, even though grub counts were not significantly lower. This relationship requires further study but is a promising lead in the development of grasses with resistance to white grubs.

Endophyte-Enhanced Insect Resistance

The discovery of the significance of endophytic fungi in grasses was an important breakthrough in turfgrass science. The initial findings of endophyte-enhanced insect resistance occurred in 1981 in a New Zealand perennial ryegrass pasture being damaged by Argentine stem weevil, and then soon after in New Jersey ryegrass plots being damaged by sod webworm. Since then, considerable work has been done and many beneficial effects of endophyte have been identified, including improved stress tolerance, persistence, and dollar spot resistance. Because endophytes are transmitted through the seed, they come in a convenient package and numerous endophyte-enhanced cultivars are currently available (see Table 5).

Several species of endophytic fungi have been identified in grasses and taxonomists continue to find new species. The endophytes in turfgrasses were being called *Acremonium* but have now been renamed *Neotyphodium*. These endophytes have been found in 13 genera of grasses, including several species of fescue, ryegrass, bentgrass and bluegrass, but not in creeping bentgrass or Kentucky bluegrass. Researchers have identified 40 insect species from six different orders that are affected by endophyte-infected grasses (see Table 2 for partial list). Some insects can detect the infected grass plants and avoid feeding on them, while others are poisoned by the toxins associated with the endophyte and have reduced survival, fitness, or egglaying. Six different groups of compounds have been identified. In addition, considerable variation exists in quantity of endophyte toxins produced. For example, ergovaline in red fescue clones ranges from 300 to 2600 ppb. Unfortunately, some of these compounds can have an adverse effect on livestock, so care must be taken when selecting grasses for establishing a pasture.

White grubs: Of special interest is the effect of endophyte on white grubs. Endophytic fungi are typically found in highest concentrations in the leaf sheath, stems and seeds, with low levels in the leaf blade, and none in the roots. However, the toxins associated with endophytes are translocated and have been found in the roots, suggesting that the endophyte might have an effect on root-feeding grubs. Several laboratory studies found decreased survival and fitness, especially with very young grubs. Results in the field were mixed. Differences in grub numbers and weight were found between cultivars in a national tall fescue evaluation trial in Rhode Island. However, only grub weights correlated with endophyte level, suggesting reduced fitness of grubs. On the hand, a study in New Jersey did find fewer white grubs on the endophyte-infected tall fescue. This type of discrepancy between studies may occur because of the numerous factors which interact to affect the expression of endophyte-enhanced insect resistance. For example, concentration of toxins is affected by density of the fungal mycelium, while density of the fungus is influenced by temperature, strain of fungus and cultivar of grass.

Fine Fescue and Chinch Bugs: Resistance to chinch bugs has been found in endophyte-infected hard, strong creeping red fescue, and Chewings fescue. A project currently underway at Rutgers is evaluating several strains of endophyte, in several fine fescue breeding populations, for their effect on chinch bugs. Trials conducted in a dixie cup found a difference in chinch bug survival between two endophyte strains in a Chewings fescue population. When given a choice in petri-dish preference tests, chinch bugs preferred endophyte-free tillers with two of the endophyte/plant combinations, but showed no preference with the third combination.

Table 2. Examples of turfgrasses where endophyte-enhanced resistance to insect pests has been found.

Tall fescue -- greenbug and other aphids, leafhopper, fall armyworm, sod webworms, Argentine stem weevil, billbugs, Japanese beetle*, southern masked chafer, grass grub

Hard fescue -- greenbug, hairy chinch bug, fall armyworm, Japanese beetle*

Chewings fescue -- greenbug, hairy chinch bug, fall armyworm, Japanese beetle*

Strong creeping red fescue -- greenbug and other aphids, hairy chinch bug

Blue fescue -- greenbug, fall armyworm

Perennial ryegrass -- greenbug and other aphids, hairy chinch bug, fall and southern armyworm, sod and bluegrass webworms, common cutworm, black field cricket, Argentine stem weevil, billbugs, Japanese beetle*, black beetle

**Resistance to Japanese beetle is variable, primarily seen with young grubs.*

This suggests variation in endophyte/plant combinations and that turfgrass breeders may be able to improve the performance of endophyte-infected grasses by selecting the best strain of fungus and putting it in the best grass. This can be done by artificially inoculating plants with the desired fungus, or by a standard breeding procedure called backcrossing. The plants containing the 'best endophyte' (parent A) are crossed with the 'best plants' (parent B) and seed is harvested only from the endophyte-infected plants (A). The offspring (50% A, 50% B and infected with endophyte) are then crossed with the 'best plants' (B) and the seed is harvested from these offspring. The offspring (25% A, 75% B) continue to be backcrossed with the original parents (B) until the desirable characteristics of the parent are obtained and high levels of endophyte are maintained.

Utilizing these pest-resistant grasses should be an important component of any I.P.M. plan. There are many factors to consider when selecting grasses for a new stand of turf, or for overseeding. I would like to suggest that level of insect resistance be one of those factors. In many cases it will not be possible to find a suitable grass with enhanced insect resistance, but an improved, vigorous turfgrass cultivar, adapted to your area, will almost always provide better tolerance and recovery from insect feeding. The lists provided in this article provide a starting point for selecting grasses but it is also a good idea to check with your local extension office. When using endophyte-infected cultivars always use fresh seed and store the seed in a cool, dry place. When seed is stored at room temperature, the endophytic fungus in the seed will start dying out after about a year.

Future Prospects

I have discussed just a few cases of insect resistance in turfgrass. Each of the examples given in Tables 1 and 2 represent opportunities to further enhance the resistance to these pests through focused breeding efforts. Very little is know of the mecha-

Table 3. Resistance of Kentucky bluegrass cultivars to billbugs

Resistant -- Eagleton, Eclipse, Washington, Wabash, America, Adelphi, Unique, Fylking, Kenblue (Common-type)

Moderately resistant -- Midnight

Highly susceptible cultivars -- Broadway, Parade, Cheri, Sydsport, Columbia

Table 4. Kentucky bluegrass cultivars with improved summer stress tolerance.*

Mid-Atlantic Type -- Eagleton, Livingston, Monopoly, Preakness, Wabash

Mid-West or Common Type -- Huntsville, Kenblue, Park (suitable for low maintenance turfs)

** This summer stress tolerance may result in better tolerance to white grub feeding.*

Table 5. Cultivars with high levels of *Neotyphodium* endophyte-infection.*

Perennial Ryegrass -- Advent, Affinity, All*Star, APM, Assure, BrightStar, Brightstar II, Calypso II, Catalina, Citation II, Citation III, Dandy, Dasher II, Envy, Gettysburg, Legacy, Manhattan II (E), Manhattan III (E), Navajo, Omega III, Palmer II, Palmer III, Passport, Pennant, Pinnacle, Prelude II, Prelude III, Prizm, Quickstart, Regal, Repell, Repell II, Repell III, Roadrunner, Saturn, Saturn II, Secretariat, Seville, Sherwood, SR 4000, SR 4100, SR 4200, Yorktown III

Tall Fescue -- Apache II, Arid, Bonanza II, Bonsai, Bonsai Plus, Coronado, Coronado Gold, Coyote, Crossfire II, Debutante, Empress, Grande, Houndog V, Jaguar III, KY-31, Lion, Masterpiece, Pixie, Phoenix, Shenandoah, Shenandoah II, SR 8200, SR 8210, Tarheel, Titan, Titan II, Tomahawk E+, Windsor II, Wolfpack
Hard Fescue - Aurora, Discovery, Reliant, Reliant II, SR 3000, SR 3100

Chewings Fescue -- Banner II, Brittany, Jamestown II, Shadow (E), Shadow II, SR 5000, SR 5100, Tiffany, Treazure, Victory (E)

Strong Creeping Red Fescue -- Jasper (E)

Sheeps Fescue -- Bighorn

**Each cultivar listed should have at least 40% of its seeds infected with endophyte. However, seed lots may vary in percent infection, and fresh, properly stored seed must be used in order to ensure viable endophyte.*

nism or inheritance of genetic resistance and no one has studied the chemistry of these resistant grass plants. Researchers are trying to inoculate Kentucky bluegrass and creeping bentgrass with useful endophytes. Crosses are being made between infected 'wild' bluegrasses and Kentucky bluegrass and eventually these may produce useful offspring. The research reported at a Turfgrass Biotechnology Workshop last summer suggest additional areas where progress may be made. Turfgrasses being grown under tissue culture have generated clonal variants with heat tolerance and disease resistance, and gene gun technology has been used to transfer genes for herbicide and disease resistance. Perhaps these approaches will yield new sources of insect resistance also.

Plant resistance is an important alternative to pesticides and many opportunities exist for researchers to further develop insect resistant turfgrasses. A cooperative effort between breeders and entomologists would greatly facilitate this work. In the meantime, turf managers can select endophyte-infected grasses and grasses which exhibit genetic resistance to insects and enhanced stress tolerance.

Dr. Jennifer Johnson-Cicalese received a master's degree from Rutgers University. In 1995, she received a Ph.D. from the University of Nebraska. Jennifer is back at Rutgers with the Turfgrass Breeding Program.

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