Benefits of endophytic grasses

By infecting grasses, endophytes provide enhanced resistance to insects and weeds.

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Endophytes are fungi belonging to the genus *Neotyphodium* that live in the leaves and stems of grasses and are carried from plant to plant only via seed. These fungi do not cause any disease in the grasses, but under most circumstances they are beneficial to the growth and survival of infected plants. This beneficial association occurs naturally in perennial ryegrass (Figure 1) and several species of fescues, but beneficial endophytes have not been found in association with Kentucky bluegrass or creeping bentgrass.

The fungal endophyte obtains all food resources from the grass host, but in return provides several benefits to the plant, such as enhanced drought tolerance, summer survival and insect resistance. New grass cultivars with endophyte-enhanced growth performance and insect resistance are being developed, and many are commercially available.

Our recent research at Ohio State University demonstrates additional benefits from planting endophyte-containing grass cultivars. We have found that fungal endophytes can provide the necessary arsenal for the grass plants to compete more effectively against common weed species and fight against root-feeding plant-parasitic nematodes. Below is an overview of the various benefits of planting endophyte-enhanced grasses.

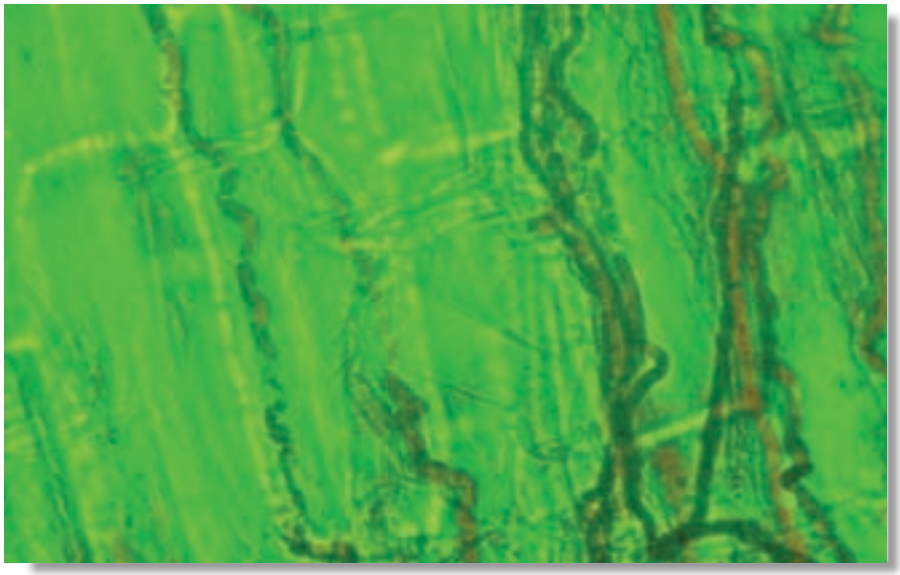

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Figure 1. An endophyte in the stem tissue of perennial ryegrass.

KEY points

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- **Endophytes** are fungi that confer benefits, including enhanced drought tolerance and insect resistance, on the grasses they infect.
- **Endophytic grasses** are generally better adapted to their environments.
- **Overseeding a grass that lacks endophytes,** such as Kentucky bluegrass, with an endophytic cultivar can improve the health of the entire stand by discouraging insect pests.
- **Higher mowing heights and less frequent mowing** increased levels of ergot alkaloids in endophytic grasses, thereby increasing the benefits derived from endophytic plants.

Wider range of adaptation

Research has provided evidence of greater persistence and growth of endophyte-containing grasses, relative to plants that lack the endophyte. Endophytes modify how plants acquire and use their available resources and may make them more widely adapted to environmental conditions. Endophyte-containing grass cultivars have greater seed survival, germination and establishment than cultivars that lack endophytes. Fungal endophytes confer drought resistance to infected plants by altering how the plant exchanges water and gasses with the environment. As a result, endophyte-infected grasses often have better summer survival. Endophyte-containing cultivars are better able to acquire scarce nutrients and therefore perform better than nonendophytic cultivars in poor-quality acidic soils and soils with low phosphorus content.

Enhanced competition against weeds

Endophyte-containing plants are generally more competitive and tend to dominate plant communities over time. Research in Indiana showed that in mixed perennial ryegrass and white clover swards, the presence of the endophyte in perennial ryegrass resulted in a significant decrease in white clover. Endophyte-containing perennial ryegrass maintained greater cover under severe insect stress, whereas stands lacking the endophyte persisted poorly and were more heavily invaded by weeds. Following drought, survival and cover of endophyte-containing tall fescue was significantly enhanced. Reduced cover of stands lacking the endophyte allowed other grasses and dicots to increase.

These results indicate that the abundance and diversity of other plant species may be reduced by competition with endophyte-containing grasses. Our research demonstrates that the competitive ability of endophyte-containing grasses could substantially contribute to reduction in weed invasion and establishment in turfgrass.

Allelopathic effects of tall fescue on red clover and birdsfoot trefoil were first demonstrated in the 1970s. Our recent research shows that endophyte-containing tall fescue and perennial ryegrass are often better able to compete against common weed species. In a

field study on newly established plots, we observed that the crabgrass population was lower in endophyte-infected stands of perennial ryegrass compared to uninfected stands. Likewise, the density of plantains (buckhorn and common) was consistently lower in stands of endophyte-infected tall fescue compared with uninfected stands. These plots were under minimal management, received no fertilizer or pesticide inputs and were mowed at a height of 3.5 inches.

Enhanced insect and nematode resistance

Endophytes provide a built-in systemic pesticide for the plant they infect. Defensive chemicals (alkaloids) are produced by the endophyte or by the grass in response to the endophyte. The alkaloids are poisonous or distasteful to many insects capable of using endophyte-free grasses. Endophyte-infected grasses are resistant to sod webworms, chinch bugs, billbugs and numerous other surface-feeding insects (Figure 2).

Previous research at Ohio State has shown that excellent control of bluegrass billbug can be obtained in Kentucky bluegrass lawns overseeded with endophyte-infected perennial ryegrass. This research also established that only about 40% of the plants in a turf sward need to contain the endophyte to obtain effective control of bluegrass billbug and sod webworm. Turfgrass insect, nematode and mite pests that can be managed with the use of endophyte-containing grasses are listed in Table 1.

Although endophytes are more effective against aboveground insect pests, they also have an impact on belowground insects and plant-parasitic nematodes. The fungus and its alkaloids are concentrated in aboveground plant tissues, but as much as 15% of the lolines and smaller amounts of ergot alkaloids may occur in tall fescue roots. Ergot alkaloids strongly deterred feeding by Japanese beetle grubs in laboratory bioassays and reduced their survival and weight gain in stands of endophyte-containing grasses in some field trials. Plant-parasitic nematode populations in the soil have been found to be smaller under endophyte-containing grasses than in endophyte-free grass stands.

Aside from the direct toxic effect that endophyte-infected plants have on many surface-feeding insects, endophytes also alter insect foraging behavior. Insects such as chinch bugs and sod webworms spend more time moving and less time feeding in stands of turfgrass containing even moderate proportions of endophyte-infected plants. This increase in movement makes the insects much more vulnerable to predators and pathogens and may be a death knell for newly hatched larvae or nymphs. These neonate insects are equipped with very little in the way of energy reserves, so they must find a suitable food source quickly or perish in the process of searching.

Effects of cultural practices

Levels of endophyte-produced alkaloids depend on several environmental factors. Seasonal variation typically shows maximal levels at the end of the growing season, but the alkaloid peramine in tall fescue shows no seasonal effects.

Temperature, sunlight and rainfall all have an impact on alkaloid production. Our own research shows that extreme temperatures repress alkaloid levels relative to the levels between 57 F (14 C) and 70 F (21 C) in tall fescue and perennial ryegrass. In a greenhouse trial, we found that the contents of different ergot alkaloids were variable at different temperatures, but there were no clear trends on the effect of temperature on any particular alkaloid between 57 F (14 C) and 77 F (25 C), thus supporting the utility of planting endophyte-containing grasses in the Midwestern United States.

In this trial, we also found that both survival and weight gain by the fall armyworm were significantly lower when feeding on endophyte-containing perennial ryegrass than the nonendophytic perennial ryegrass at all temperatures.

Both nitrogen and phosphorus fertilizers can alter the levels of alkaloids in tall fescue. The application of nitrogen increases the concentration of major ergopeptide alkaloids in tall fescue cultivar Kentucky 31. At the University of Georgia, it has been demonstrated that the source of nitrogen is also important, as all con-

PESTS AFFECTED BY ENDOPHYTIC TURF

Insects
Annual bluegrass weevils, *Listronotus* (=*Hyperodes*) spp.
Armyworm, *Pseudaletia unipuncta*
Black cutworm, *Agrotis ipsilon**
Bluegrass billbug, *Sphenophorus parvulus*
Bluegrass webworm, *Parapediasia teterrella*
Bronzed cutworm, *Nephelodes minians*
Chinch bug, *Blissus leucopterus leucopterus*
Cranberry girdler, *Chrysoteuchia topiaria*
Fall armyworm, *Spodoptera frugiperda**
Greenbug, *Schizaphis graminum* (Rondani)
Hairy chinch bug, *Blissus leucopterus hirtus*
Japanese beetle, *Popillia japonica**
Larger sod webworm, *Pediasia trisecta*
Southern masked chafer, *Cyclocephala lurida**
Vagabond crambus, *Agriphila vulgivagella*

Mites
Clover mite, *Bryobia praetiosa*
Winter grain mite, *Penthaleus major*

Plant parasitic nematodes
Dagger nematode, *Xiphinema* sp.
Lance nematode, *Hoplolaimus* spp.
Lesion nematode, *Pratylenchus* spp.
Pin nematode, *Longidorus* sp.
Ring nematode, *Crionemoides* spp.
Spiral nematode, *Helicotylenchus* spp.
Stubby root nematode, *Tylenchorhynchus* spp.

*This species can feed and develop on endophytic grasses, but individuals that do are slower to develop than individuals feeding on nonendophytic grasses.

Table 1. Major insect, mite and nematode pests of cool-season turfgrasses that can be potentially managed with endophyte-infected grasses.

centrations of NO_3-N increased ergopeptide alkaloid content as opposed to NH_4^+-N, which was effective only at high concentrations. Ergot alkaloid accumulation in roots of tall fescue increased linearly with the availability of phosphorus in the soil. Alkaloid concentration in the shoots increased with increasing phosphorus availability in the soil at levels of 17 to 50 milligrams of phosphorus per kilogram but declined at 96 milligrams of phosphorus per kilogram of soil.

We have found that the levels of ergot alkaloids in endophyte-containing perennial ryegrass and tall fescue are affected by common cultural practices such as mowing height and frequency. The major ergot alkaloids, including ergonovine, ergocristine and ergocriptine, significantly increased in tall fescue when mowing height increased from 1 to 3 inches (Figure 3). Increased mowing height also has been shown to reduce masked chafer grub populations at the University of Kentucky.

In another greenhouse experiment, we tested the effect of two mowing frequencies — weekly or once every two weeks — on ergot alkaloids. Mowing height was 2 inches. We found that decreased mowing frequency caused a fivefold increase in the amount of ergovaline and a 2.6-fold increase in ergonovine (Figure 4).

In both the above experiments we used the fall armyworm as a bioassay insect to detect the impact of our treatments on the resistance of grass plants to insects. We found that the dry weight of the fall armyworm decreased as the concentrations of ergonovine in the shoots increased — a result of less-frequent mowing.

Figure 2. A single endophyte-infected perennial ryegrass plant remains untouched in the midst of a stand of fine fescue severely damaged by chinch bugs. Note the encroachment of weeds (thistles) into the surrounding area that was once inhabited by the fescue.

Systemwide effects of endophytes

Fungal endophytes can provide a wide range of benefits for turf stands, but it is important to recognize that the benefits of insect resistance, competitiveness against weeds and broader range of adaptation are not completely independent of one another. For instance, we have conducted controlled studies that demonstrate how resistance to insects also provides a competitive advantage against weeds. Because endophyte-infected grasses are not preferred by insects, these grasses suffer much less damage and, as a result, are much stronger competitors against dandelions and other common weed species. Likewise, because endophyte-infected plants are more efficient at acquiring nutrients from the soil, they are less likely to become overrun by weeds during

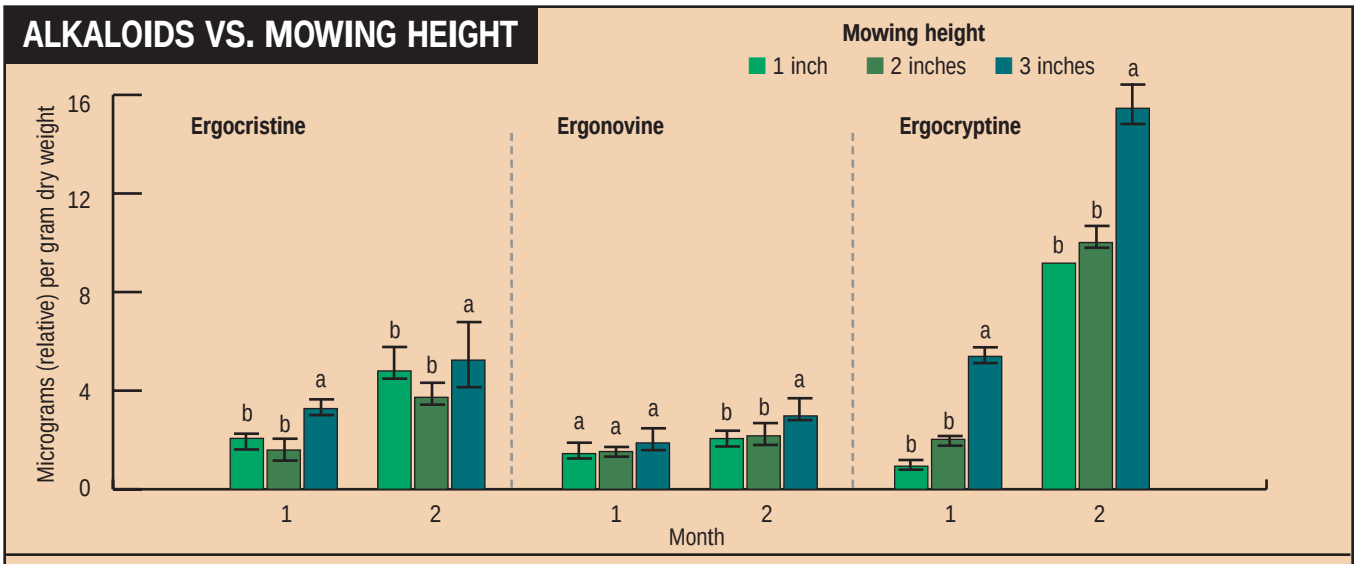

Figure 3. The effect of mowing height on concentrations of major ergot alkaloids in tall fescue shoots after one or two months in the greenhouse at 77 F (25 C). Grass was mowed weekly at a height of 1, 2 or 3 inches. Within each month, mowing height treatments with the same letters are not significantly different.

drought or nutrient shortages. This phenomenon of multiple, simultaneous and interacting benefits provides the foundation of a systems-oriented approach to turfgrass management.

Introducing endophyte-infected grasses

Realizing the benefits of endophyte-infected grasses does not always require complete turf renovation. Because only moderate proportions of endophyte-infected grasses are necessary to provide resistance against many insects, overseeding pre-existing stands is a simple and effective option. Previous research at Ohio State indicates that overseeding stands of Kentucky bluegrass with endophyte-infected perennial ryegrass at a rate of 1 or 2 pounds/1,000 square feet (using a slicer-seeder) can significantly alter the composition of the turfgrass stand within a short period. Overseeding in the fall will provide resistance to billbugs, chinch bugs and sod webworms the following year. However, over time perennial ryegrass will tend to outcompete the Kentucky bluegrass and can eventually take over a stand. Therefore, this management option is only practical in situations where perennial ryegrass is an adequate agronomic substitution for Kentucky bluegrass.

Seed storage

To protect the endophyte in the seed, it is very important to store the seed in a cool, dry place. Temperatures exceeding 99 F (37 C) for one to two weeks can eliminate the endophyte from the seed even though the seed may still be viable. It is also important to use fresh seed that has been stored under cool conditions. A grow-out test can also be performed to confirm endophyte viability in the seed.

Conclusions

The use of endophyte-containing grasses offers a sustainable solution for some turfgrass pest management problems. Endophyte-containing grass will have mitigating effects on pest problems, including weeds, insects and plant-parasitic nematodes, and can help ensure persistence through environmental stresses such as drought or nutrient shortage.

Although it is clearly not possible to implement these changes in all situations (particularly on golf courses), perennial ryegrass is a viable substitute for Kentucky bluegrass in roughs and in collar regions around tees and greens that are often prone to damage by surface-feeding insects. Also, on southern golf courses, perennial ryegrass is often used on fairways and other shortcut areas during the winter, when bermudagrass goes dormant. Simple cultural practices such as reduced mowing frequency, increased mowing height, increased nitrate nitrogen and phosphorus, and reduced irrigation frequency boost alkaloid (toxin) levels in endophyte-containing plants. The increase in alkaloid levels enhances the benefits from planting endophyte-containing grass cultivars. The resulting lesser use of chemical pesticides and surfactants also favors colonization and establishment of natural enemies, parasites, predators and pathogens of turf pests.

The use of endophyte-containing grasses in turf systems is practical because endophyte-containing grasses can be easily incorporated into pest management systems by overseeding in existing turf or by establishing new turf sites containing mixtures of endophyte-enhanced and endophyte-free grasses.

Acknowledgments

The authors thank Seppo Salminen, Ph.D., for providing data on cultural practices and endophyte alkaloid production. This work was supported in part by the United States Department of Agriculture NRI grant number 00-35316-9249.

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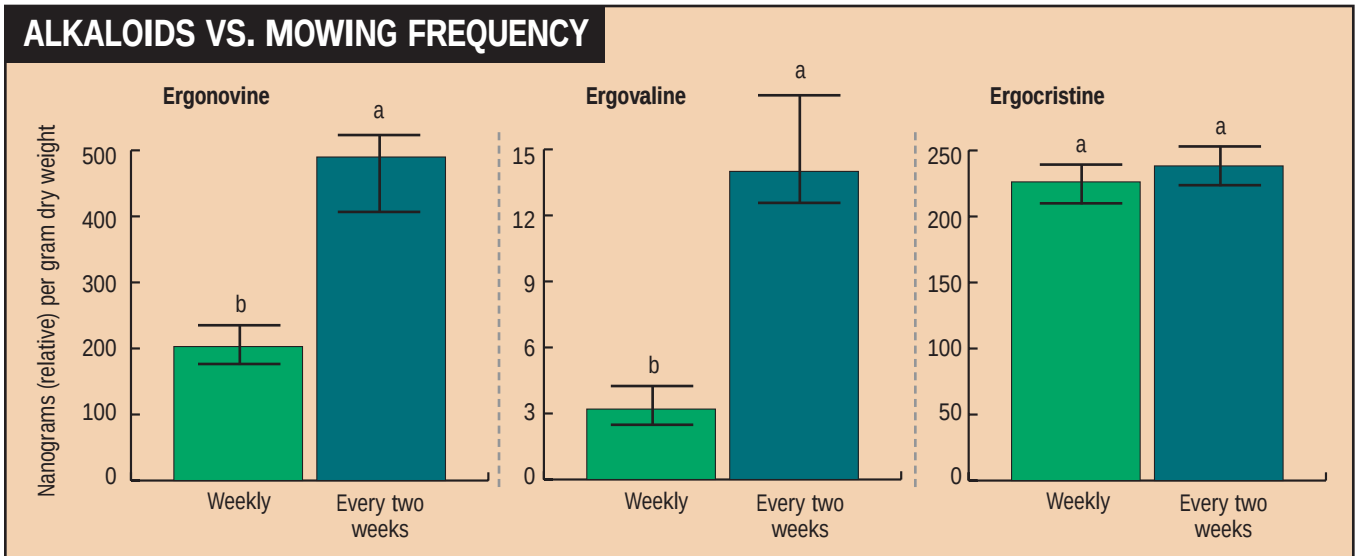

Figure 4. The effect of mowing frequency on concentrations of major ergot alkaloids in tall fescue shoots after two months in the greenhouse at 77 F (25 C). Grass was mowed at a height of 2 inches once a week or once every two weeks.Within each month, mowing height treatments with the same letters are not significantly different.