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The Tall Fescue Endophyte

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Tall fescue (Festuca arundinacea Schreb.) is the most important cool-season grass in the United States, providing the primary ground cover on some 35 million acres. It is a versatile perennial used to provide pasture and hay for livestock, for various turf purposes, and for erosion control. Commonly referred to as simply "fescue," this widely adapted, persistent grass is seed propagated, tolerant of a wide range of management regimes, and it produces good forage yields. Laboratory nutritive analyses of fescue compare favorably to those of many other cool-season grasses.

Fescue became popular as a forage grass in the United States soon after the release of the variety "Kentucky 31" in 1943. During the 1940's and 1950's there was phenomenal interest in, and widespread planting of, this grass throughout the lower Midwest and a large portion of the South. In much of the South, fescue filled a void where no other cool-season perennial forage grass was adapted.

Unfortunately, this new grass was not without its shortcomings. Its forage was of relatively low palatability to livestock, and performance of animals grazing it was erratic and often disappointingly low. In addition, some cattle grazing fescue occasionally developed lameness and sometimes lost portions of their feet or tails during fall and winter. The term "fescue foot" was used to refer to this serious, although relatively infrequent, problem. Another problem noted was termed "fat necrosis ," which involves the deposit of hard fat in the abdominal cavities of cattle. Fat necrosis is associated with heavy application of broiler litter or nitrogen fertilizer to fescue pastures.

In addition, cattle grazing fescue often developed a chronic unthrifty condition, especially apparent during the summer months. This condition came to be widely referred to by the terms "summer syndrome,' "summer slump," "fescue toxicosis," or "fescue toxicity." Furthermore, mares grazing tall fescue pastures often aborted, produced stillborn foals, had thickened or retained placentas, or produced an inadequate quantity of milk. For many years these problems remained a mystery, despite vigorous research efforts.

Discovery of Fescue Endophyte

It was not until the mid-1970's that an amazing discovery regarding fescue was made. USDA scientists in Georgia associated an endophytic fungus with poor gains of beef cattle in an on-farm situation, and this was subsequently confirmed in replicated research at Auburn University in Alabama.

The terms "fescue fungus," "endophyte," "fungal endophyte," and "fescue endophyte," have all been used to denote the organism in question. "Endo" (within) plus "phyte" (plant) means a plant that lives within another plant. In this case, the plant (endophyte) is a fungus, originally identified as Epichloe typhina and later renamed Acremonium coenophialum. It is generally accepted that these terms refer to the same organism.

Two characteristics of the endophyte have great practical importance. First, the organism does not affect either the growth or appearance of the grass, and it requires a laboratory analysis to detect its presence. Second, it is seed transmitted and apparently not transmitted in any other way. Thus, once a noninfected stand is established, it can be expected to remain that way unless infected seed are introduced into the pasture and become established.

Endophyte Effects

Animal Response

Studies with animals consuming endophyte-infected fescue have shown the following responses in comparison to animals grazing non-infected fescue: (1) lower feed intake; (2) lower weight gains; (3) lower milk production; (4) higher respiration rates; (5) higher body temperatures; (6) rough hair coats; (7) more time spent in water; (8) more time spent in the shade; (9) less time spent grazing; (10) excessive salivation; (11) reduced blood serum prolactin levels; and (12) reduced reproductive performance. Some or all of these responses have been observed in numerous studies in dairy cattle, beef cattle, and sheep consuming endophyte-infected pasture, green chop, hay and/or seed.
The initial steer grazing study at Auburn University showed an 82% increase in average daily gain (ADG), and a 42% increase in gain per acre with endophyte-free fescue compared to endophyte-infected fescue (Table 1). Interestingly, gains were reduced throughout the grazing season, and not just in the summer. Other grazing studies with steers in Kentucky, Alabama, Georgia, Missouri, Texas, Tennessee, North Carolina, and Maryland have also shown ADG's 50 to 100 percent greater on low-endophyte as compared to high-endophyte tall fescue pastures.

Table 1. Grazing days, beef gain/acre, average daily gain, and gain/animal of steers grazing A. coenophialum-infected and non-infected tall fescue pastures, Marion Junction, Alabama 1978-82.

Tall Fescue Pasture	Animal days/acre	*Beef gain (lbs/acre)	Avg. daily gain (lbs)	Gain/steer (lbs)
Non-infected	240	426	1.82	318
Fungus-infected	311	301	1.00	185

**Adapted from: C.S. Hoveland and co-workers. Steer Performance and Association of Acremonium coenophialum Fungal Endophyte on Tall Fescue Pasture. Agron.]. 75:821-824. 1983.*

Presence of the endophyte affects grazing livestock in many ways. In a Georgia study, steers on low-endophyte fescue grazed 43 to 65 percent of the time between noon and 4:00 p.m., while steers on high-endophyte fescue grazed only 5 to 21 percent of the time during the same period. Steers moved from high- to low-endophyte fescue did not resume normal grazing habits for 26 days, indicating a residual effect. Mississippi State University workers found that the body temperatures of cattle did not return to normal until 56 days after removal from infected fescue. Other studies in Alabama and Kentucky have shown increased gains and intake, as well as lower body temperatures, of steers consuming endophyte-free seed or hay when compared to animals consuming infected seed or hay. Research conducted in Kentucky revealed a 39 percent reduction in forage intake and 37 percent decrease in milk production during summer in lactating dairy cows consuming endophyte-infected fescue. In addition, these cows lost weight, while animals consuming non-infected fescue gained weight.
Other Kentucky work showed that beef cows had a 35 percent lower pregnancy rate when grazing highly infected, as compared to endophyte-free, fescue pastures (Table 2). Similar responses have been found in Missouri. Furthermore, researchers at Auburn University obtained a sharp drop in pregnancy rates of replacement beef heifers grazing infected fescue, almost in direct proportion to the level of endophyte infection (Table 3). Several other studies have shown sharply reduced milk production of beef cows grazing infected fescue.

Table 2. Pregnancy Rate in Beef Cows

	Pregnant
Low Endophyte Fescue	94%
High Endophyte Fescue	59%
Difference	35%

N. Gay and co-workers, University of Kentucky, 1986 (3 years)

Table 3. Effect of Fungus-Infected Tall Fescue Pastures on Growth and Reproduction of Replacement Beef Heifers at Two Locations (Black Belt and Tennessee Valley Substations) in Alabama, 1984-86*

Fungus Level	A.D.G	Pregnant
0-5%	1.20	96%
25-60%	0.96	82%
80-99%	0.87	55%

**Adapted from: S.P. Schmidt and co-workers. Fescue Fungus Suppresses Growth and Reproduction in Replacement Beef Heifers. Highlights of Agricultural Research Vol. 33, No. 4, Winter 1986. Ala. Agric. Exp. Station.*

Endophyte-Distribution

Over 4,500 producer-submitted fescue samples from 30 states and several foreign countries have been tested at Auburn University, and approximately 90 percent had some level of infection. The average infection level for pasture samples was about 60 percent with a range of infection from 0 to 100 percent. The fungus is especially prevalent in areas where Kentucky 31 is the predominant variety.

Since most fescue fields are endophyte-infected, most producers who use fescue as a forage grass are not obtaining the level of animal performance which would otherwise be possible. The relationship between level of infection and animal performance among animal species and classes has not been adequately studied. However, data from several states suggest that each 10 percent increase in endophyte level can result in a reduction of 0.1 pound in ADG of growing beef animals.

Research in many states has demonstrated conclusively that the fescue endophyte is associated with negative effects on animal performance. The mechanism is as yet unknown but a toxin is strongly suspected. Regardless, the economic impact of this problem is immense, perhaps exceeding $500 million annually in terms of lost beef gain alone!

Potential Adverse Aspects

New Jersey studies found that sod webworm damage is greater on endophyte-free than on endophyte-infected, turf-type fescues. Also, greenhouse work in Alabama and Kentucky has shown that aphids prefer endophyte-free fescue. Tests in Louisiana and Georgia revealed that survival, growth, and development of fall armyworm larvae fed endophyte-infected fescue were reduced. Kentucky researchers found evidence that alkaloids in endophyte-infected fescue are associated with increase resistance to insect feeding. A greenhouse study at Auburn University revealed over three times as many spiral nematodes associated with the roots and soil of endophyte-free than with endophyte-infected fescue plants. Work in Arkansas showed significantly fewer nematodes associated with endophyte-free fescue in field tests in that state.

Endophyte infection has also been associated with morphological and physiological drought resistance mechanisms in tall fescue. In Georgia, endophyte infection seemed to decrease stomatal aperture and gas exchange. Also in Georgia, trials with a single clonal line of fescue that infected plants survived 40 days of severe drought stress, while only 25 percent of endophyte-free plants survived. Under moderate drought stress the same plants were observed to exhibit leaf roll if infected, but not if endophyte-free. Infected plants were also observed to have thicker, narrower leaves, which presented less surface area for evaporation.

Grazing livestock prefer endophyte-free over endophyte-infected fescue. If given the choice, they will spend far more time grazing endophyte-free fescue, and their intake will he greater, thus requiring a lower stocking rate.

An apparent difference in vigor has been observed between infected and non-infected pastures in some environments. This has usually been seen only in new plantings, but in tests conducted in stressful

environments, stand loss was greater in established endophyte-free pastures.
These findings have important implications. First, while fescue is regarded as a forage crop which is easy to establish, that may be less accurate when the fescue is endophyte-free. It appears that greater attention to management is needed for endophyte-free fescue, especially during the establishment year. Thus when establishing endophyte-free fescue, a producer should carefully follow all recommendations, including time of planting, fertilization, etc.
Secondly, since overgrazing is more likely to occur when the endophyte is not present, endophyte-free fescue requires a higher level of grazing management. In particular, overgrazing should be avoided during the establishment year or in highly stressful environments. Top growth should not be grazed or clipped shorter than 3 or 4 inches, especially during the first year.
In addition, severe stress may be more likely to result in stand decline of established stands of endophyte-free fescue. Thus, fields which are only marginally adapted to fescue should not be planted to endophyte-free fescue.
Finally, while insects and other pests do not currently limit the use of endophyte-free fescue, it is possible that pest problems may be greater with endophyte-free fescue. It may be advisable to monitor such pastures more closely in the hope of eliminating any such problems before they cause serious damage.
Relatively little information is available regarding long term stand persistence of endophyte-free fescue. However, endophyte-free fescue stands established in 1974 at the Auburn University Black Belt Substation have persisted and remained endophyte-free even though separated from infected fields only by a barbed wire fence.
Based on current knowledge and experience, endophyte-free fescue can be expected to persist well, with the exception of plantings exposed to highly stressful situations. However, even if periodic reestablishment became necessary, the improved animal performance on endophyte-free pastures would easily justify reestablishing a highly infected field. Despite the need for somewhat higher management levels, the opportunities provided by endophyte-free fescue are great.

Strategies for Coping with the Endophyte

Livestock producers who have established, or who plan to establish, fescue fields should develop an intelligent endophyte strategy based on research findings. The following is a review of options available for avoiding or minimizing endophyte effects.

Establishing New Fescue Stands

When planting a new fescue field, a livestock producer should use seed known to have little or no (certainly less than 5 percent) endophyte infection. In a few states, fescue seed tags must state the percent endophyte infection. The importance of knowing the level of endophyte infection in seed can hardly be overemphasized. For example, when a beef producer uses endophyte-free seed, it can increase returns by $75.00 or more per acre per year. This increased beef production can be expected every year for the life of the stand!
New fescue plantings, even if endophyte-free, should normally include a legume. Kentucky research indicates that clover in an endophyte-free fescue stand will further increase young animal gains by 0.2 pounds per animal per day. However, the primary justification for planting a legume with fescue is that it can result in 2 or more years of excellent animal performance with little or no nitrogen fertilizer expense.
White clover (preferably a Ladino type), seeded at the rate of 2 to 4 pounds per acre, is the best clover companion in most fescue pastures. However, red clover, at a rate of 10 to 15 pounds per acre broadcast, or 8 pounds per acre drilled, is another good possibility, especially when fields are to be cut for hay. Other legumes such as birdsfoot trefoil or alfalfa may also be useful in certain situations.
It should be noted that interseeding legumes at the same time endophyte-free fescue is seeded involves some risk. Endophyte-free fescue seedlings may grow more slowly than endophyte-infected fescue, therefore decreased competitive ability of the fescue may result. For the same reason, it is not advisable to seed small grain, especially ryegrass, at the same time endophyte-free fescue is being planted.

Dealing With Existing Endophyte-Infected Stands

Producers with established fescue fields need to assess their situations carefully. Existing fescue stands should be tested on a field-by-field basis. Several states now have laboratories for determining endophyte level. County agricultural agents can provide information regarding cost, sampling methods, and laboratory address(es).

Once the level of endophyte in existing fescue pastures is known, a producer can select the best option for dealing with the problem. The best way to handle one field may not be best for another. Four general approaches are available:

1. Manage-to-minimize-the-effect--Endophyte effects on animals can be minimized with management practices. Grazing and/or clipping management that keeps plants young and vegetative will result in better animal performance. Likewise, if fescue is cut for hay in the boot stage, better animal performance will be obtained than from late-cut hay. Other practices such as chain harrowing, fertilizing, pest control, creep grazing, and rotational grazing will result in improved overall pasture quality and animal performance.
2. Avoid-the-Endophyte--Use of other forage species avoids the endophyte. Using grasses other than infected fescue for summer grazing will avoid the endophyte during the summer when fescue forage quality is low. Since animal performance is adversely affected by feeding infected fescue hay, feeding of hay of another species can also be helpful.
3. Dilute-the-Endophyte--The endophyte or its products can be diluted through the use of other feeds in the diet. Growing legumes with infected fescue is an attractive option. Many studies have shown increased pasture production, higher live-weight gains, and improved pregnancy rates when pastures are renovated to include legumes.
4. Kill infected stands and replant--Low-endophyte or endophyte-free seed is now readily available in most areas of the United States where fescue is grown. Several excellent new varieties of fescue have recently been released, and others are expected. Careful consideration should be given to choosing low-endophyte seed. A new variety that is simply "low-endophyte" or "endophyte-free" will be of little or no value if it is not productive in the area in which it is to be grown. When selecting a variety, attention should be given to adaptation, agronomic performance, animal performance, persistence, and pest resistance. The best source of variety information is university variety trials.

The cost of converting from high- to low-endophyte fescue varies. Where fescue is used in rotation with other crops, the only difference in cost will be the small price difference between low- and high-endophyte seed. Where the sod is killed with a herbicide and the seed drilled into the killed sod, the cost may be $30 to $50 per acre. Where existing fescue is destroyed by tillage and immediately replanted, the cost may be as high as $100 or more per acre.

Any infected fescue field which is to be replanted should not be allowed to produce seed during the reestablishment year. Seedhead formation should be prevented by heavy grazing, clipping, or by chemical application. This is for the purpose of preventing the establishment of volunteer infected plants. Under usual storage conditions the endophyte will die within one or two years. Thus, any volunteer plants from old seed will usually be endophyte-free or have a very low level of endophyte infection. Unfortunately, the germination level of fescue seed may drop sharply during long-term storage, depending on temperature and humidity conditions. Furthermore, the vigor of seedlings resulting from planting old seed is likely to be reduced.

Methods of replacing endophyte-infected stands include:

A. Rotation--Rotating with other crops, followed by seeding low-endophyte fescue, is an excellent approach. There are many options ranging from no-till corn or a summer annual grass to longer term rotations involving a perennial such as alfalfa or three annual crops. With any rotation option, careful consideration must be given to herbicide residues, erosion hazards (leave all waterways--it's better to have a highly infected sod waterway than a non-infected gully), and the complete destruction of the old fescue.

B. Prepared Seedbed - Certain situations permit destroying the old sod through tillage, preparing a

seedbed, and then replanting non-infected fescue. However, it is often difficult to completely destroy an old fescue sod by tillage.
C. Chemical Kill No-Till - Where methods A and B are not feasible, chemical kill of infected stands followed by no-tillage planting is the only remaining option. This technique can be used to go directly from infected fescue to non-infected fescue, or other forage crops can be used in a rotation. It is critical that chemicals be used effectively, thus killing all the existing infected fescue. In some cases there may be common bermudagrass or other species which must also be killed, requiring the use of more than one herbicide or a higher herbicide rate. Effective sod kill requires attention to label instructions and striving for optimum environmental and plant conditions that will permit greatest chemical effectiveness. Consult Extension Service recommendations on chemicals, rates, and time of application.

Best results from no-till tests have been found with late summer or early autumn seedings of fescue. Although chemical kill has been satisfactory in spring, summer drought and competition from warm season annual weeds tend to reduce stands of spring-seeded fescue.
A particularly effective approach is to use no-till plantings of annual forages after killing infected fescue. For example, infected fescue can be chemically killed in the spring and a summer annual grass can be drilled into the killed sod, followed by no-till planting of non-infected fescue in the fall. Similarly, fescue can be killed in the fall followed by sod planting of winter annuals and, if desired, sod planting of a summer annual grass the next spring. In this case, non-infected fescue would be planted one year after the infected fescue was killed. Use of annuals in this manner smothers fescue plants which escaped the chemical treatment and also reduces the likelihood of insect damage to seedling fescue plants.

Current Outlook

Discovery of the fescue endophyte constitutes a breakthrough of immense proportions. Most scientific advancements come in small increments. In this case, we are seeing a dramatic increase in the performance of animals grazing a tough, widely adapted perennial grass. Despite some potential disadvantages, the proper establishment and management of endophyte-free fescue constitutes an unprecedented opportunity for thousands of livestock producers to obtain animal performance far superior to what they would obtain by establishing, or keeping, endophyte-infected stands.
There are many endophyte-related studies in progress, including several aimed at developing a better understanding of fescue foot, fat necrosis, and horse reproductive problems. Future discoveries may answer remaining questions relating to this problem and perhaps provide additional solutions. It seems clear that application of the existing and forthcoming technology relating to this breakthrough will have an immense impact on livestock production in the fescue-growing region of the United States, and perhaps in many other parts of the world.