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Tall Fescue, Endophytes and Alkaloids, and Fescue Toxicosis

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Introduction

Tall fescue (*Schedonorus arundinaceus*, syn. *Lolium arundinaceum*, formerly *Festuca arundinacea*) is the predominant forage species on over 1 million acres of hay and pastureland in Virginia and over 35 million acres across the U.S. Although it is known as a high-quality forage, tall fescue has been linked with livestock health issues and other disorders due to a fungus associated with the plant. Understanding this fungus can help producers develop whole-farm management strategies to mitigate its effects.

Tall Fescue Growth and Nutritive Value

A cool-season perennial grass, tall fescue is well adapted to most of Virginia's soils and climate, and it is productive over much of the growing season. The forage has many desirable agronomic traits. It is relatively easy to establish, forms a dense sod under grazing, and persists under a wide range of environmental and management conditions. Tall fescue can tolerate drought, and on poor or hard-to-manage soils, it is the most reliable perennial cool-season grass for forage or conservation purposes. Tall fescue is a vigorous seed producer and strong competitor in mixed stands and thus tends to encroach over time until it becomes the dominant forage in a pasture. Its tendency for encroachment and survivability are evidenced by the fact that it was not planted on a widespread basis in the U.S. until the 1940s, but within a few decades it had become the dominant pasture grass in many Eastern states.

Tall fescue generally starts growth in late winter or early spring but it can remain green and continue growing throughout mild winters, particularly in warmer regions such as southeastern Virginia. As is typical for cool-season grasses, tall fescue has greatest growth rates during spring and fall (Figure 1.). Tall fescue leaves (and thus nutrient concentrations) hold up better to frost and freezes than other forages, making it superior to all other perennial cool-season grasses in its ability to be stockpiled for late fall and winter grazing. This characteristic makes tall fescue a

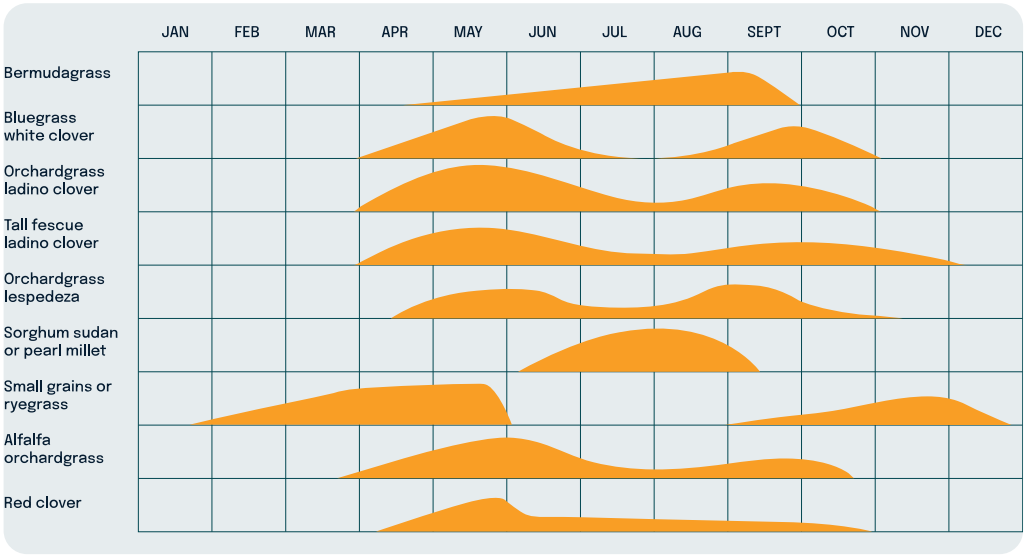

Figure 1: Cool and warm-season grass growth curves. Among cool-season grasses, tall fescue is uniquely suited for stockpiling. (Image from "The Agronomy Handbook," VCE publication 424-100.)

key resource for livestock producers, as it enables them to increase grazing days (Allen et al. 1992) and dramatically reduce winter feeding costs.

Tall fescue forage is generally of high quality and digestibility. The species is nutritionally similar to other cool-season perennial grasses when grazed or harvested at a similar stage of growth. First-cutting tall fescue hay is frequently harvested when too mature, resulting in lower digestibility, energy, and protein content than desired. This problem can be addressed with sound management, however. High levels of sugars accumulate in tall fescue during the fall and early winter; this may be advantageous for fall-calving herds, which have high energy requirements during those months. It also has potential for summer stockpiling, particularly for brood cows. Visit "Using a Summer Stockpiling System to Extend the Grazing Season," (https://augusta.ext.vt.edu/content/dam/augusta_ext_vt_edu/files/Using_a_Summer_Stockpiling_System_to_Extend_the_Grazing_Season.pdf) and related video resources at https://pubs.ext.vt.edu/ANR/ANR-289/ANR-289NP.html.

Despite its positive agronomic traits, many Virginia producers are often disappointed with the performance of livestock grazing on tall fescue. Mid-summer gains are often inferior to gains of animals grazing other grass or grass-legume pastures. Milk production of lactating beef and dairy cows also is often reduced. In beef systems, this contributes to lower calf weaning weights. In addition, reductions in calving rates, particularly for spring-calving herds, can be attributed in part to tall fescue consumption.

Fungal Endophytes, Alkaloids, and Plant Performance

While poor performance and negative responses of animals consuming tall fescue were observed for several decades, it was not until the late 1970s that the cause of these responses was discovered. Many tall fescue plants are infected with a fungus, called an endophyte because it grows inside the plant (*endo* = within; *phyte* = plant). This fungal endophyte is now classified as *Epichloë coenophialum* (Figure 2). It does not affect the outward appearance of tall fescue. Epichloë fungi produce ergot alkaloids during their normal lifecycle within the plant. When consumed, these toxins cause a number of disorders for a variety of mammalian species.

Although the phrase "endophyte infected" is typically used in a negative sense, the actual fungal endophytes are not toxic per se. The fungi produce several types of alkaloids that benefit the plant hosts. For example, peramine is an alkaloid that provides resistance to insect pests.

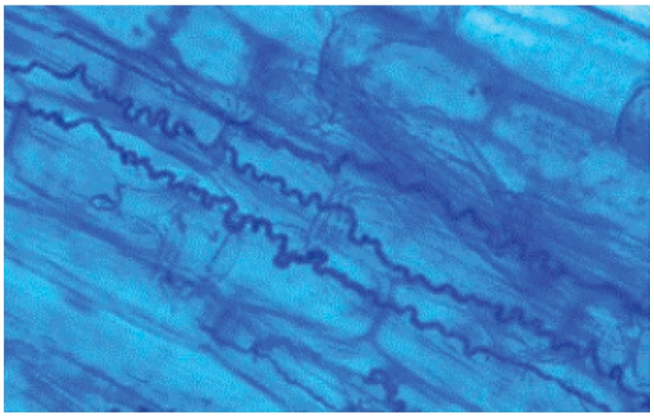

Figure 2: The endophyte is a fungus that grows in the cell walls within the fescue plant. Many plant species have endophytes, and not all fungi are toxic. In this microscope image, the fungus is stained and clearly visible as dark blue squiggly lines.

However, the wildtype endophytes also produce ergovaline, the primary ergot alkaloid that causes toxic effects to mammals. This molecule (Figure 3) is chemically similar to lysergic acid diethylamide, more typically known as LSD. Problems related to ergovaline consumption are discussed in the section on livestock disorders below.

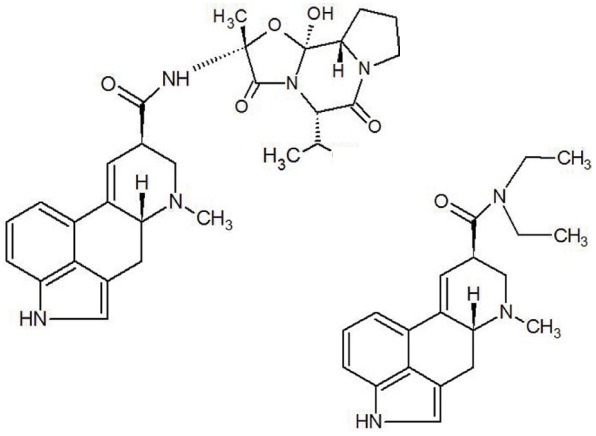

Figure 3: Ergovaline (top), the primary mammalian toxin in fescue, is produced by wildtype fungal endophytes. Ergovaline contains a lysergic acid base coupled to a group of amino acids. The lysergic acid in ergovaline is structurally very similar to lysergic acid diethylamide, the psychoactive drug known as LSD (bottom).

The fungal endophyte resides in plant cell walls during the winter, the fungus survives in living plants in crown tissues near ground level. The fungus does not reproduce sexually; to be transmitted from one generation to the next, the fungus grows into the seed. As fescue seed heads develop, the fungus grows from the base of the plant up the elongating stem and invades most of the developing seeds. Spreading through seed is the only known means of transmitting the fungus to the next generation. An uninfected tall fescue plant cannot "catch" the fungus from an infected plant. This knowledge is important for the management of tall fescue stands.

Infection of tall fescue by the endophyte is a good example of a symbiotic association in nature. The plant provides a home and energy for the endophyte, and the fungus in turn helps make the tall fescue plant more resistant to stress by generating alkaloids and altering plant root architecture. When infected with the endophyte, tall fescue has greater ability to withstand environmental stresses such as drought and low soil fertility. The endophyte also supports resistance to insects and other plant pests such as slugs and mites by deterring their feeding. Livestock grazing infected fescue also have lower intake, which may help prevent overgrazing. Although no clear evidence exists indicating that livestock can distinguish between infected and uninfected fescue, infected plants do have a competitive advantage in mixed pastures — particularly when overgrazed — because the stress tolerances conveyed by the endophyte support greater plant persistence. Thus, endophyte-free fescue and other grass species are more likely to die out over time.

The fungus itself typically is less present in leaf tissue, and alkaloid concentrations are several times higher in plant stems and stem bases than in leaves. This might suggest that maintaining tall fescue in a leafy, vegetative condition may reduce ingestion of toxins. However, such healthy, productive plants typically support fungal growth and have higher alkaloid concentrations.

Initial efforts at resolving fescue toxicosis issues involved removing the endophyte from tall fescue. The endophyte can be killed by treating seeds with fungicide, or by storing the seed for over 12 months in sub-optimal conditions. Many studies show the performance benefits for animals that graze endophyte-free or low-endophyte tall fescue varieties. (Low endophyte varieties have seed containing less than 5 percent wildtype endophytes, and therefore very low or nonexistent alkaloid levels.) Livestock that graze endophyte-free pastures do not have negative responses (Table 1). However, these cultivars largely have proven unsuitable in Virginia, particularly in low management situations or in more challenging environments, because they lack persistence. Thus, subsequent efforts to reduce negative effects of infected fescue largely focused on diluting the pasture with legumes or feeding supplements, although this too has limitations.

Discovery of fungal endophyte strains that do not produce alkaloids prompted a new round of research and Extension efforts. These are often called "novel," "nontoxic," or "friendly" endophytes, and they produce little or no ergot alkaloid. Currently, there are eight novel fescue varieties on the market Studies have shown that livestock grazing low- or nontoxic endophyte varieties show little or no fescue toxicosis symptoms. In addition, fescue varieties that contain novel endophytes have similar resistance to pests and challenging environmental conditions as Kentucky 31 and other cultivars with wildtype endophytes.

Some producers have experienced loss of novel endophyte stands; this may reflect bad seed (without viable endophytes), poor soil fertility, poor grazing management, or some combination of these factors. It is important to note that the Grassland Alliance (a consortium of industry and university partners) have developed protocols for ensuring that only good seed with viable endophytes are sold. Most importantly, many farmers have converted to novel endophyte tall fescue and have enjoyed very long stand life. Significant benefits can be realized even if only a portion of a farm's toxic fescue fields are converted to novel fescue. Refer to www.grasslandrenewal.org for more information on novel fescue. For more information on how to minimize the effects of toxic fescue, refer to VCE Publication "Strategies for Managing Endophyte-Infected Tall Fescue – A Whole-Farm Approach" (https://www.pubs.ext.vt.edu/SPES/SPES-163/SPES-163.html).

Livestock Disorders from Endophyte-Infected Tall Fescue

"Fescue toxicosis" is the broad term that encompasses the three major disorders observed in cattle that

consume tall fescue infected with the wildtype endophyte. Other ruminants also experience lower performance in response to alkaloid consumption, although the effects may be less obvious.

Symptoms of fescue toxicosis include:

- Reduced feed intake
- Low weight gains
- Decreased milk production
- Higher respiration rates
- Elevated body temperatures
- Rough hair coats
- More time spent in/near water and shade
- Less time spent grazing
- Excessive salivation
- Reduced blood serum prolactin levels
- Reduced reproductive performance

Some or all of these symptoms can be observed in dairy cattle, beef cattle, and sheep that consume tall fescue pasture, green chop, hay, and/or seed containing ergot alkaloids. Symptoms are most noticeable when temperatures exceed 88 degrees F and generally are reduced in cooler weather (Hemken et al. 1981).

In cattle, the three disorders of fescue toxicosis include "summer slump," "fescue foot," and "bovine fat necrosis." These disorders occur in part because ergot alkaloids are potent vasoconstrictors, meaning the alkaloids constrict (or reduce the size of) the animal's blood vessels. This reduces blood circulation, especially to the extremities. Summer slump (or "summer syndrome") reflects the lower-than-expected performance of cattle on tall fescue, particularly during summer. Because blood flow is constrained, these animals typically have higher core body temperatures and seek shade and water to dissipate heat. Reducing intake is another mechanism for reducing heat stress. This condition is further compounded because these animals often have rough hair coats (Figure 4).

Figure 4: Heifers suffering from fescue toxicosis (top) display classic symptoms of long, rough hair coats. Their matted coats also reflect their efforts to dissipate heat by wallowing – in this case, the animals created the mud by splashing water from their water tub. Heifers grazing novel endophyte fescue pastures (bottom) during summer have shed most of their rough hair. (Photos courtesy of Dr. Matt Poore, North Carolina State University.)

Fescue foot (Figure 5) generally describes lameness associated with alkaloid consumption. Empirical observations suggest these symptoms are most likely to occur with rapid drops in temperature in the fall, before the body has an opportunity to adjust to the change in weather. Animals with fescue foot may have redness of the coronary band, the junction of the hoof and the leg's hairline. Changes in vein architecture also are associated with fescue foot. As this condition worsens, sores at the band will appear; in severe cases, gangrenous conditions will set in, causing sloughing of hooves or feet. Cattle can also lose the tips of tails (Figure 6), ears, or both because these extremities do not stay warm enough to prevent frostbite.

Figure 5: A yearling heifer displays significant injury from fescue foot. The middle image shows the blood vessels of a heifer with fescue foot. Please note that the dye (blood flow) only extends to an area between the dew claws and the top of the hoof. The outcome is there is no blood flow to the toes, and the tissue around the toes and claws is slowly dying. Contrast the altered vein architecture with the venogram of a normal foot, right. Note the blood flowing throughout the foot. (Photos courtesy of Dr. Terry Swecker, Virginia-Maryland College of Veterinary Medicine.)

Figure 6: Missing switches (circled) are a telltale sign of fescue toxicosis. During cold weather, reduced blood flow to the extremities increases the potential for frostbite. (Photo courtesy of Morgan Paulette, VCE agent, Pulaski County.)

Bovine fat necrosis is characterized by the abnormal accumulation of masses of hard fat in the abdominal cavities of cattle. This fat can cause digestive or calving problems. Occurrence of fat necrosis is generally limited to cattle grazing pure tall fescue pastures that have been heavily fertilized with poultry litter or nitrogen fertilizer. Older cows may be more subject to this problem. Animals with little exposure to fescue also can develop fat necrosis when exposed to toxic pasture (Figure 7).

Figure 7: This graphic image shows the deposits ofnecrotic(dead) fat tissue that enveloped the intestines in a case of bovine fat necrosis. The hardened fat constricted the digestive tract, preventing the animal from eating. (Photo courtesy of Kevin Jennings.)

Effects on Beef Stockers

Research throughout the southeastern U.S. suggests that gains in yearling cattle are reduced by an average of 0.1 pounds per day with each 10 percent increase in the level of endophyte infection in a pasture, although in Virginia, the loss may not be that high. Historical data collected in Virginia (Table 1) suggest that losses may be closer to 0.04-0.06 pounds per day with each 10 percent increase in infection level. This may be due to differences in pasture composition (with more orchardgrass and bluegrass) or a result of Virginia's cooler climate compared to other southeastern states.

Even though fescue toxicosis is often referred to as summer syndrome, poor steer gains can occur throughout the growing season (Table 1). Nevertheless, the extent to which animal gain suffers usually increases as temperature increases, and observed increases in daytime temperatures in our region (EPA 2001) are likely to increase the severity of this problem.

One way to improve late-season gains is to stockpile tall fescue for winter grazing. It is important to wait until January to graze. Toxin levels drop significantly after several freeze and thaw cycles, and grazing studies indicate no difference in stocker performance between fescue types when grazing commences in January.

Table 1. Endophyte infection of tall fescue reduces stocker cattle performance in Virginia[1]

Location and Parameter	Low endophyte[2]	High endophyte[3]	Difference
Southwest Virginia	**lb/head/day**		**%**
ADG[4] (Apr-July 1988-91)	1.88	1.48	27
ADG (July-Oct 1988-91)	0.92	0.74	24
ADG (Apr-Oct 1988-91)	1.37	1.10	25
ADG (Apr-Oct 1995-96)	1.30	0.93	40
Hair Coat Score[5] (Oct 1988-91)	2.2	3.6	39
Serum prolactin[6]	65.4	1.4	-98
Southern Piedmont Virginia	**lb/head/day**		**%**
ADG (Apr-July 1988-91)	1.76	1.25	41
ADG (July-Oct 1988-91)	1.20	0.87	38
ADG (Apr-Oct 1988-91)	1.45	1.04	39
Hair Coat Score[5] (Oct 1988-91)	2.2	3.6	39
Serum prolactin	59.3	1.3	-98

[1] Sources: Tully et al. 1994 and Allen et al. 1997, 168-172.
[2] < 5% endophyte-infected
[3] > 70% endophyte-infected
[4] ADG = Average Daily Gain
[5] Hair Coat Score: 1 = smooth and shiny; 5 = rough and dirty
[6] Although measured in stockers in this study, substantial prolactin depression occurs when lactating cows graze toxic fescue. This response indicates that lactating cows would produce less milk.

Effects on Breeding Cattle

Cows grazing toxic, endophyte-infected tall fescue generally have reduced weight gain and lower pregnancy and calving rates (Table 2). Mortality for newborn calves can also occur when cows have little or no milk at calving. Reduced milk production by the dam also lowers calf rates of gain and weaning weights. Gains and pregnancy rates of heifers decrease as toxic endophyte levels increase. Reductions in calving rates seem to be due to early embryonic death and a failure to conceive (which may be confounded by poor body condition and heat stress on toxic tall fescue). Estrus cycling may be affected by toxic tall fescue. Bulls also demonstrate lower reproductive performance after consumption of ergot alkaloids, possibly a result of reduced semen quality (Pratt et al. 2015).

Effects on Milk Production

Dry cows and pregnant dairy heifers grazing toxic, endophyte-infected tall fescue in late summer and fall can have reduced milk production after freshening. Reductions as great as 45 percent in beef cows, 50 percent in beef heifers, and 60 percent in dairy cows have been reported. This occurs due to reduced feed intake and prolactin (the hormone supporting milk production), and likely also due to a reduction in blood flow to the mammary gland (see Table 1). Fall calving heifers may be particularly challenged to deliver and support a healthy calf and continue their own growth because fescue alkaloid concentrations are very high in fall. A weak calf and mother with low milk supply (agalactia) can result in calf loss in our environment.

Influence of Cattle Breed on Response to Toxic Fescue

Although Angus and Brahman-Angus cross steers both exhibit decreased gains when grazing infected tall fescue, the magnitude of the decrease may be less for the Brahman-cross steers. Brahman cattle are inherently more heat tolerant, and so they may be better adapted to resist or tolerate the higher body temperatures associated with consuming toxic tall fescue in hot weather. However, with the heavy discounts for Brahman cross cattle in Virginia, cross breeding with Brahman cattle is not recommended.

Table 2. Pregnancy and calving rates on toxic endophyte-infected fescue

Reference	Pregnancy or Calving rate E+	Alternative Forage	Type of Alternative Forage
Schmidt et al. 1986	55	96	low endophyte
Beers and Piper 1987	80	90	low endophyte
Gay et al. 1988	55	95	endophyte-free
Peters et al. 1992	72	91	endophyte-free
Essig et al. 1993	58	88	endophyte-free
Brown et al. 2000	56	93	bermudagrass
Burke et al. 2001	85	85	endophyte-free
Watson et al. 2004	94	94	novel endophyte
Coblentz et al. 2006	87	83	endophyte-free, orchardgrass
Coffey et al. 2007	45	85	novel endophyte
Drewnoski et al. 2009	54	65	novel endophyte, endophyte-free
Looper et al. 2010	61	84	bermudagrass during breeding
Caldwell et al. 2013	44	80	novel endophyte
Caldwell et al. 2013	90	95	novel endophyte during breeding

Other European breeds may have more resistance to heat stress than traditional British breeds and thus perform better when consuming ergot alkaloids.

Variability in the resistance of individual cattle to ergot alkaloids also exists within breeds. A number of genes have been correlated with greater calf performance from dams that routinely graze toxic tall fescue. For example, the ability to shed hair is associated with greater productivity on toxic tall fescue, and hair coat scores may be useful to distinguish resistant from nonresistant cattle. Some have observed that cows that slick off earlier typically wean heavier calves, and this trait appears to be moderately heritable. Producers likely have been selecting (if subconsciously) for more tolerant cattle over many generations. Of course, not bringing home a calf puts added selection pressure on cows that are sensitive to the alkaloids.

In recent years the genetic test T-Snip was proposed to identify cows that were tolerant or intolerant to tall fescue. Early results were encouraging, but mixed results in field application have led to low use of that test. Several breeds have explored a fescue tolerance EPD, but currently no breed has a functional EPD for tall fescue tolerance. It has been proposed that both the Hair Coat Shedding and Pulmonary Arterial Pressure EPDs in Angus cattle may be related to fescue tolerance, but that is still a subject of research. The Slick Hair trait that is found in calving Senepol and other central and south American breeds imparts some tolerance to tall fescue. The trait is caused by a mutation in the dopamine receptor which makes females very resilient when challenged with ergot alkaloids. It is recommended that farmers with toxic tall fescue pastures seek genetics with a background of selection on toxic tall fescue pastures whenever possible.

Effects on Small Ruminants

Small ruminants are also susceptible to ergot alkaloids in similar ways, although they may be better able than cattle to detoxify them. Some research indicates that small ruminants can eliminate ergot alkaloids from their body faster than cattle. Weight gains of lambs consuming toxic tall fescue are often diminished due to reduced dry matter intake and digestibility. Growing kids also seem to be negatively affected by ergot alkaloids, but less work has been done with goats. Although ergot alkaloids cause vasoconstriction in small ruminants, the effects may be mitigated to some degree by the tolerance of some breeds to heat stress. Very little work has been done on the

reproductive performance of small ruminants on toxic tall fescue, but ewes fed toxic tall fescue seed during gestation delivered much smaller lambs than ewes fed endophyte-free tall fescue seed.

Effects on Horses

Mares grazing endophyte-infected tall fescue pasture have lower conception rates, increased embryonic mortality, and increased abortions, resulting in fewer live foals. Pregnant mares are most sensitive to infected tall fescue during the last three months of gestation, and especially during the last 30 days; negative responses can occur even in the presence of low ergot alkaloid levels. For live foals, gestation lengths and weights can be greater, which can increase the difficulty of foaling (dystocia) and increase foal and mare deaths. Placentas, which often are retained, can be thicker and difficult for foals to shed. Because foals in turn may be weak at birth, this can further increase their mortality. Mares can have lower blood prolactin levels which may cause agalactia (no milk production). Lactating mares placed on infected tall fescue pastures have been known to stop lactating within a few days. Many of the symptoms associated with fescue toxicosis in pregnant and early-lactation mares can be treated with domperidone under veterinary supervision. There is no firm evidence that any other class of horse is adversely affected by toxic tall fescue pasture. In fact, in most areas of Virginia, endophyte-infected tall fescue is probably one of the best, most durable forages for horse pasture. For more details on managing fescue problems with horses, visit VCE publication 406-475, "Broodmares Grazing Tall Fescue Pastures or Fed Tall Fescue Hay Require Careful Management and Close Observation," (http://archive.li/cOBC5).

Extent of Endophyte Infection and Alkaloid Levels in Virginia Pastures

Sampling in the 1980s revealed that 75 percent of fields surveyed had fungus present in 50 percent or more of the plants. More recent research by Extension agents across Virginia suggests current infection levels may be higher than in the 1980s. Of pastures sampled, 100 percent were infected with the toxic endophyte, and 80 percent of pasture samples had infection levels of 70 percent or more. Infection levels of 40 percent or more can generally be expected to produce moderate to severe adverse effects in animals, although no level of infection can be considered completely safe.

Information on sampling tall fescue pastures can be found in VCE publication SPES-21P, "Sampling Tall Fescue for Endophyte Infection and Ergot Alkaloid Concentration," (https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/spes/spes-21/SPES-21.pdf). Quantifying endophyte infection levels in toxic fescue pastures is a "first pass" strategy for assessing potential for toxicosis issues on the farm. However, knowing levels of infection is not the same as knowing the level of alkaloids present in a pasture. Scientists have not reached universal consensus on what levels are toxic to livestock, but many place the dietary threshold for disorders at about 400 parts per billion. Sampling efforts from around the state indicate toxin levels are often much greater than the 400 ppb threshold.

Summary

Tall fescue is a productive, nutritious forage and the backbone of Virginia's pasture systems. However, the plant typically contains alkaloids produced by a fungal endophyte, and these toxins cause numerous problems collectively known as fescue toxicosis. In cattle, physiological conditions associated with alkaloid consumption include fescue foot, summer slump, and bovine fat necrosis. Alkaloids also cause reductions in milk production and can lower reproductive success. Horses should be moved from toxic-laden fescue in late gestation to reduce the risk for lower milk production at foaling. Sampling in Virginia suggests typical alkaloid levels in pastures are greater than the presumed 400 ppb-threshold that causes clinical symptoms of fescue toxicosis in cattle. Sampling may be the first step in understanding the level of severity in your pastures. Whole-farm management strategies should be developed to deal with fescue toxicosis issues. Considerations should be made about how to manage pastures and conserved forages, nutrient source and application rates, and livestock selection and production, among other factors. Information on these topics can be found in related VCE publications.

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