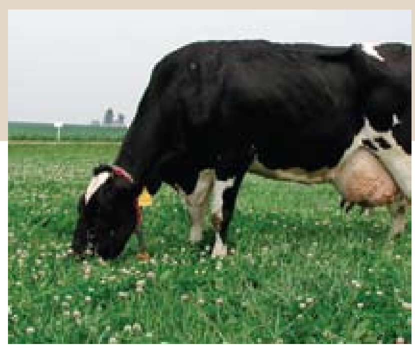
Forage Fescues in the Northern USA



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Executive Summary

Tall fescue, meadow fescue and festulolium have potential value as forages for grazing operations in the northern USA. Meadow fescue is the most cold tolerant of these grasses, with excellent forage quality and palatability, and relatively high drought tolerance. Tall fescue has the highest yield potential, good palatability for soft-leaf varieties and excellent heat and drought tolerance. Festulolium exhibits high forage quality and good summer production. A cold-tolerant festulolium variety has been bred for Wisconsin.

The naming and classification of the fescues has caused some controversy over the years. The fine fescues, also known as true fescues, are classified in the genus *Festuca*. The broadleaf fescues, which include tall fescue and meadow fescue, were originally grouped into *Festuca*. As the science of plant classification grew more sophisticated, the broad-leaf fescues were later grouped—incorrectly—in the same genus as the ryegrasses. They are now classified in their own genus: *Schedonorus*.

For years, tall fescue has had a poor reputation in the USA for causing disease in livestock, because most fescues contain a naturally occurring fungus called an endophyte. Each species of fescue has its own unique endophyte that lives in the leaves, stem, seed and crown tissue of infected plants. Endophytes and fescue plants benefit from a mutualistic relationship. The plant provides the fungus with a home, water and nutrients. The fungus produces two types of alkaloids that are released into the plant: lolines and ergovalines. Lolines protect the plant from drought, heat and predation by insects, but do not cause health problems in cattle. Ergovalines are the main cause of health disorders such as leg and foot ailments, loss of balance and digestive problems.

While tall fescue endophytes produce both protective and harmful alkaloids, the meadow fescue endophyte does not produce the ergovaline alkaloid that makes livestock sick. Furthermore, meadow fescue cannot become infected with the harmful endophyte found in tall fescue.

Figure 1. University students collect grass samples for identification.

Endophyte-free varieties of tall fescue can be created by exposing the seed to ambient temperatures (at least 75°F) for 12 to 18 months. However, the endophyte is important for heat and drought tolerance in the South.

Meadow fescue

In 1990, Charles Opitz of Mineral Point, Wisconsin, discovered an unknown, highly palatable grass growing in a remnant of the ancient oak savanna ecosystem on his farm. Opitz quickly realized that this grass was different from other grasses on his farm. USDA-ARS and UW-Madison researchers eventually identified the mystery grass as meadow fescue (Figure 1). Further research has identified old stands of meadow fescue on hundreds of farms in the Driftless Region of southwestern Wisconsin, northwestern Illinois, northeastern Iowa and southeastern Minnesota.

Meadow fescue comes mainly from northern Europe and mountainous regions of southern Europe. It was introduced to the USA and Canada in the early 1800s. Meadow fescue arrived in the Driftless Region at least 100 years ago. By 1943, tall fescue was the fescue of choice in the USA due to its consistently higher forage yields and superior disease resistance. By the early 1950s, meadow fescue was essentially forgotten in the USA.

Meadow fescue reappeared on the research scene after the managed grazing movement of the 1980s gained momentum. Early on-farm research showed that, while tall fescue varieties provided more forage, the superior palatability of meadow fescue resulted in equal consumption of tall and meadow fescue. A meadow fescue breeding program was initiated at the University of Wisconsin and the USDA-ARS. This program first bred 'Azov' meadow fescue for high forage availability under managed grazing. 'Hidden Valley' meadow fescue was later developed from plants collected on the Opitz farm.

When cut six times per year, 'Hidden Valley' and 'Azov' meadow fescues yielded slightly less forage than both tall fescue and orchardgrass, but more forage than the European 'Bartura' meadow fescue. 'Azov' meadow fescue consistently yielded more forage than 'Hidden Valley'. This was likely due to the intensive selection for high forage yield under managed grazing. Meadow fescue is well suited to frequent, managed grazing, but not as well suited as taller grasses to hay management systems.

Rising global temperatures appear to be causing meadow fescue to die out at lower altitudes in southern Europe. But, despite the same trend toward elevated average temperatures, meadow fescue populations have rapidly increased in the Driftless Region. It is very possible that meadow fescue plants in the Driftless region have a special endophyte that helps protect them from extreme climatic conditions. Meadow fescue populations have resided in the Driftless Region for over 100 years, allowing the best-adapted plants to survive.

Tall fescue

Tall fescue deserves greater consideration for pastures in northern states than it has received in the past. While tall fescue is the dominant cool season grass in the southeastern USA, it is not widely grown in Wisconsin due to animal health concerns. Removal of the fungal endophyte is a solution to the disease issue. The authors have observed no effect of fungal endophytes—either toxic or animal friendly—on persistence or yield of tall fescue in Wisconsin.

When managed for hay or pasture, tall fescue is among the highest yielding perennial grasses grown in Wisconsin. The greatest yield advantage usually occurs in mid-summer and autumn, when the productivity of other grass species tends to slump. Laboratory measures of forage quality are no better or worse than other grasses, so greater yield should equate to greater per-acre meat or milk production.

Wisconsin research has demonstrated that cattle prefer grasses other than tall fescue when offered a choice. Older tall fescue varieties have stiff leaves with barb-like projections on the edges, but new varieties with softer leaves are currently on the market. While no published data document improved palatability of soft-leaf fescues, unpublished observations suggest that some of them are indeed more palatable.

Forage intake and milk production on pastures planted to endophyte-free tall fescue and kura clover were studied at the UW-Madison Arlington Agricultural Research Station. Results indicated that there should be no concern about pasture intake or milk production by dairy cattle on endophyte-free tall fescue. In another research project at the Arlington Station, beef steers gained approximately 22 percent more weight per acre on tall fescue compared to orchardgrass.

Festulolium

Festuloliums are hybrid crosses of ryegrasses and fescues. Most of these crosses were made by European plant breeders who selected plants that had the physical appearance of ryegrasses, but with the improved stress tolerances of fescue. In the USA, plant breeders used the opposite approach, transferring the superior palatability and digestibility of ryegrass into tall fescue. Following research trials in the late 1980s, Wisconsin breeders developed the 'Spring Green' festulolium variety that could survive Wisconsin's harsh winters.

As fescues gain popularity in grazing operations in the northern USA, interest and local knowledge of their culture and management continue to increase. Seed companies have made additional varieties available within this region. Forage fescues have a bright future in managed grazing systems in the northern USA.

Introduction

Fescues have become one of the most popular and valuable grasses for use in managed grazing and soil conservation systems in the north central and northeastern United States of America. Although they are not native to North America, they have adapted well since their introduction from Europe in the 19th and 20th centuries. Both tall and meadow fescue have drought tolerance, grazing tolerance and defoliation recovery traits that are superior to many other perennial grasses. Tall fescue has superior heat tolerance, allowing it to remain productive under most growing conditions. Meadow fescue has superior cold tolerance that provides long-term persistence under severe winter conditions, including open winters with low temperatures, dry winds and little snow cover. This publication focuses on the use and culture of meadow fescue, tall fescue and festulolium, with additional information on their history and introduction to North America.

What are the fescues?

All plants are classified according to a hierarchical system of groups, the lowest levels being genus and species. The fescues represent a genus called *Festuca*. Plant classification systems are not perfect, as they are based on the most advanced scientific concepts at the time a plant is classified. As new scientific discoveries and methods allow us to better understand the internal workings of plants, they can be classified into more meaningful groups. Furthermore, scientists do not all agree on how best to classify plants, or on the results of our efforts to classify plants. Because of these issues, there is a lot of controversy over the naming and classification of the fescues.

Within the genus *Festuca*, there are six main groups of plants, only two of which have any commercial value. In common terms, these are the fine fescues and broad-leaf fescues. The fine fescues include many species that are native to Europe, Asia and North America. They include sheep fescue, hard fescue, red fescue, Chewing's fescue and blue fescue, among many others. These grasses are unique because they have rolled leaves that tend to be fairly stiff. The edges of the leaves are rolled up so that they almost touch each other and resemble a tube. This trait gives the fine fescues excellent drought tolerance, because moisture is conserved inside the tube. These plants are valuable forages in their native habitats, which include cool-season regions of Europe and Asia and some cool-season rangelands in western North America. They are also one of the main pillars of the turfgrass industry, providing one of the most important plant groups for low-maintenance turf and use in deep shade. Scientists agree that the species within the fine-fescue group are "true" fescues—that is, they are classified correctly.

Unfortunately, the broad-leaf fescues are at the heart of the controversy over fescue classification. The broad-leaf fescues are a very small group of plants, including tall fescue and meadow fescue. They have been intensively studied during the past 60 years, generating a wealth of morphological, physiological and genetic data that has essentially told us that these are not true fescues. The broad-leaf fescues do not look like, nor are they closely related to, the fine fescues. The early plant classifiers got it wrong when they lumped these plants into the genus *Festuca* with the fine fescues. To be fair, this choice was based on all the information available at the time, mainly the shape of the seed head and the seeds themselves. To make matters worse, now that scientists are trying to fix this problem, different groups of scientists do not agree on how to reclassify the broad-leaf fescues.

Since the late 1980s, tall fescue has been renamed three times and meadow fescue has been renamed once. The first name change occurred as a direct result of some very old research results and new advancements in DNA technology. Scientists have known since the 1940s that fescues and ryegrasses can be crossed to create fescue-ryegrass hybrids. This phenomenon implies a very close genetic relationship that is often taken into account when naming or classifying plant species. However, scientists could not determine how closely the broad-leaf fescues were related to ryegrasses until DNA markers became very inexpensive. As it turns out, they are very close indeed, so this lead to the first reclassification of broad-leaf fescues from *Festuca* to *Lolium,* which is the genus name for ryegrass.

At this point, plant taxonomist Stephen Darbyshire renamed tall fescue from *Festuca arundinacea* to *Lolium arundinaceum* and meadow fescue from *Festuca pratensis* to *Lolium pratense*. Darbyshire is the leading worldwide expert on fescue taxonomy. Edward Terrell, the world's expert in ryegrass taxonomy, made the next renaming and reclassification. He felt that the broad-leaf fescues with their panicle-type heads (like oats) could not belong to the same genus as the ryegrasses with their spike-type heads (like wheat). So he renamed tall fescue *Schedonorus arundinaceus*. Finally, tall fescue was renamed *Schedonorus phoenix* because the rules of naming plants were violated with the name Terrell proposed (*Schedonorus arundinaceus)*. *Schedonorus phoenix* is now the official, internationally recognized, scientific name of tall fescue.

There are only five existing species of broad-leaf fescues, all of which are descended from five ancestral species. The genetic relationships of these species are shown in Figure 2. Meadow fescue is the only one of the five ancestral species known to remain in existence. The other four ancestral species might have been members of other groups within the genus *Festuca* and one of them might be perennial ryegrass, but we don't know if this is the case. The five ancestral species are all diploids, meaning that they have two sets of chromosomes. Each set of ancestral chromosomes has been given a name (X, Y, P, G_1 and G_2) as indicated in Figure 2. There are two tetraploid species with four sets of chromosomes, each resulting from natural hybrids between two diploid ancestors. Both of these tetraploids are fairly rare and confined to narrow geographic regions: the Appennine Mountains of central Italy and mountainous regions of North Africa. The most common forms of tall fescue and giant fescue are both hexaploids, having six sets of chromosomes that derive from three different ancestral diploid species. Meadow fescue is the only common ancestor of tall and giant fescue.

Meadow fescue and tall fescue are, by far, the most common broad-leaf fescues both in the wild and in agriculture. They are the only broad-leaf fescues with wide commercial appeal and value in cool-season areas around the world, including the north central and northeastern USA.

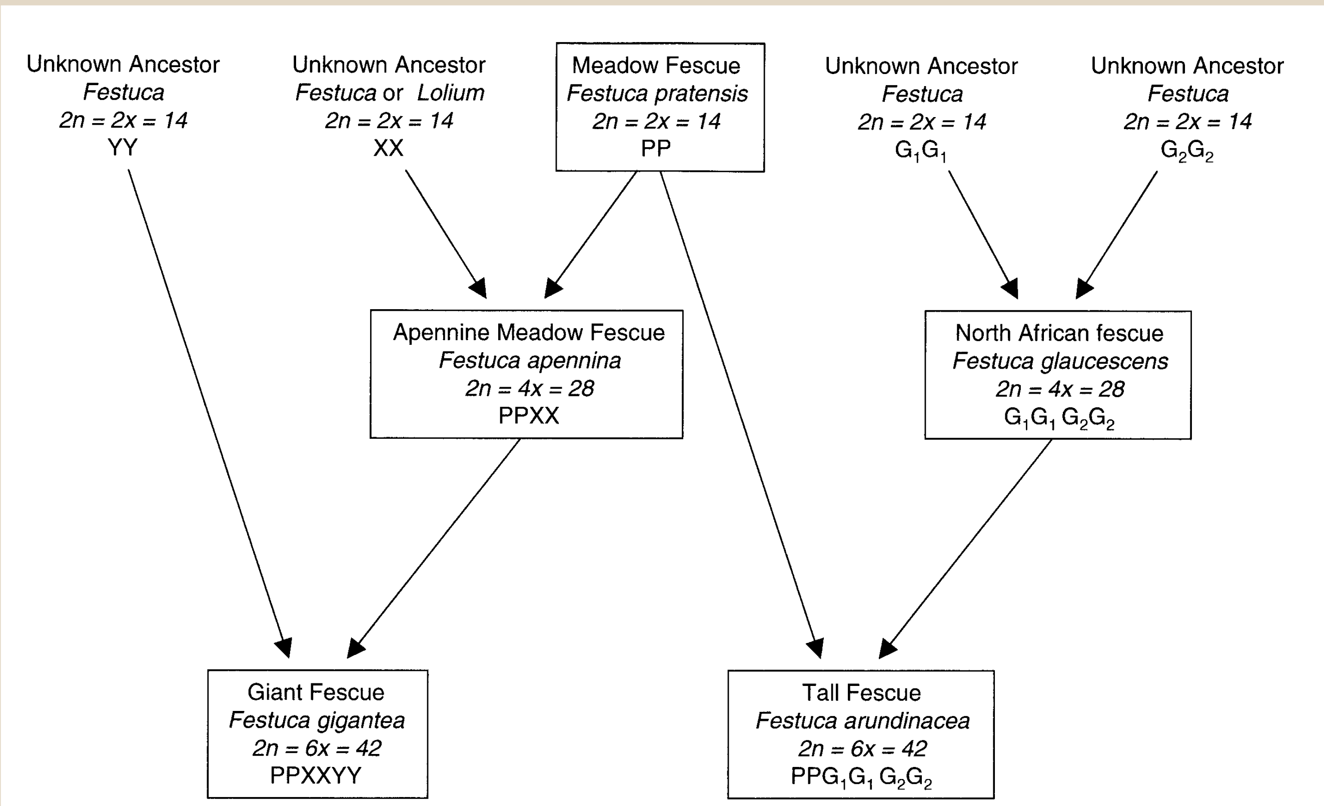

Figure 2. The ancestral and genetic relationships among five species of broad-leaf fescues. The five boxes identify the five members of this group that are known to exist today and have been positively identified. The five letters (X, Y, P, G1, and G2) are names that have been given to each set of chromosomes that originate from the five ancestral species.

Endophytes in broad-leaf fescues
Most broad-leaf fescue plants contain a naturally occurring endophyte. An endophyte is a fungus that lives inside the plant, growing between its cells as the plant matures (endo=inside, phyte=plant). The fungus lives in high concentrations in the seed of infected plants. It begins to grow with the new seedling immediately after germination, penetrating most stem and leaf tissue. The fungus lives indefinitely in its host plant, overwintering in crown tissue or growing into seeds and propagating itself in daughter plants.

While the endophyte cannot survive outside of the host plant, it isn't a parasite. Instead, the fungus forms a mutualistic relationship which also benefits the host plant. The host plant provides the fungus with water, nutrients and a structure in which to grow and reproduce. In turn, the fungus produces alkaloids that are released into the plant, helping to protect the host from drought, heat and hungry herbivores. Recent studies on tall fescue have clearly shown that the endophyte is essential for the long-term survival of this forage in extremely warm climates. Studies on tall fescue have shown that the endophyte has no effect on host survival in predominantly cool climates.

Remarkably, each host plant species has its own unique endophyte species. There is absolutely no cross-compatability between the endophytes contained in meadow fescue and tall fescue, suggesting that each of these three host plant species has co-evolved for hundreds of thousands of years along with its own endophyte. Each organism changes slightly as the earth's climate changes, as droughts come and go and as insect and herbivore populations change. The net result is a natural relationship that allows each organism to thrive and reproduce.

There are two general types of alkaloids produced by fescue endophytes—lolines and ergovalines. Lolines protect the plant from drought, heat and predation by insects. They do not cause health problems in livestock.

The second type of alkaloid produced by endophytes—ergovalines—cause a disease called ergotism in animals. Ergotism affects blood circulation and the nervous system. Epidemics of human poisoning from ergot-infected rye grain were common in Europe during the Middle Ages, causing a condition known as St. Anthony's Fire. The ergot toxins cause constriction of blood vessels resulting in a burning sensation in the limbs and in severe cases, gangrene, loss of limbs and abortion. Ergot-infected grains are also known to cause hallucinations and irrational behavior.

Ergot alkaloids produced by fungal endophytes are the same as those responsible for St. Anthony's Fire in humans. These ergovalines protect plants from herbivory, including consumption by livestock. They are the main cause of diseases and syndromes of livestock grazing tall fescue, such as leg and foot diseases ("fescue foot"), rough hair coat, digestive problems and loss of appetite.

While tall fescue endophytes produce both lolines and ergovalines, the meadow fescue endophyte produces only lolines. There has been a huge, worldwide research effort to find a tall fescue endophyte that produce lolines, but not ergovalines.

Figure 3. Meadow fescue grass and seedheads

Meadow fescue
Meadow fescue (Figure 3) comes mainly from northern Europe and mountainous regions of southern Europe. It was introduced to the USA and Canada in the early 1800s. During the early 1900s, it was deemed sufficiently important by the USDA to maintain annual records of meadow fescue seed production in the USA. Seed production of meadow fescue averaged 100,000 pounds per year from 1929 to 1951. The forage seed trade was not very sophisticated in the late 1800s or early 1900s, so no records exist of particular varieties or strains that were popular at the time. Meadow fescue seed was most

Figure 4. Meadow fescue growing in a remnant of the oak savanna ecosystem on the Charles Opitz farm near Mineral Point, Wisconsin.

likely propagated, produced and sold by species name only. One variety from eastern Canada, 'Ensign', was named in the early 20^{th} century.

The forgotten grass

In 1990, Charles Opitz of Mineral Point, Wisconsin, discovered an unknown grass growing in a remnant of the ancient oak savanna ecosystem on his farm (Figure 4). These plants formed a dense ground cover in deep shade underneath a thick canopy of oak trees at the top of a hill. According to land records and verbal communication, the area had been in pasture for over 100 years and had never been planted to improved varieties. We eventually identified the mystery grass as meadow fescue, based on DNA markers (Figure 5). The overall evaluation was based on over 500 plants collected from many different sites on the Opitz farm. Eleven plants that represented the range of DNA marker variation are shown in Figure 5, relative to the control species (meadow fescue, tall fescue, perennial ryegrass and Italian ryegrass).

After watching his cattle graze meadow fescue within this oak grove, Opitz quickly realized that this grass was unlike any other grass on his farm. It was highly palatable and his cows consumed it vigorously, even plants that had ripe seed heads. As his grazing management evolved in the 1990s and became more intense[1], Opitz observed that the meadow fescue was spreading from the hilltop oak grove into gullies and open areas around the hill. Theorizing that cattle had eaten ripe seed and were spreading this seed in their manure, he began a systematic program of spreading meadow fescue around the farm.

As with most managed grazing systems in the northern USA, the Opitz farm had a surplus of feed in the spring when grass growth is very rapid. This always led to hay production on many acres of land that would be grazed later in the season. Wanting to propagate his newly discovered grass on other parts of the farm, he allowed some acres of meadow fescue to produce ripe seed before harvesting large round bales of hay. By systematically feeding these hay bales on other pastures

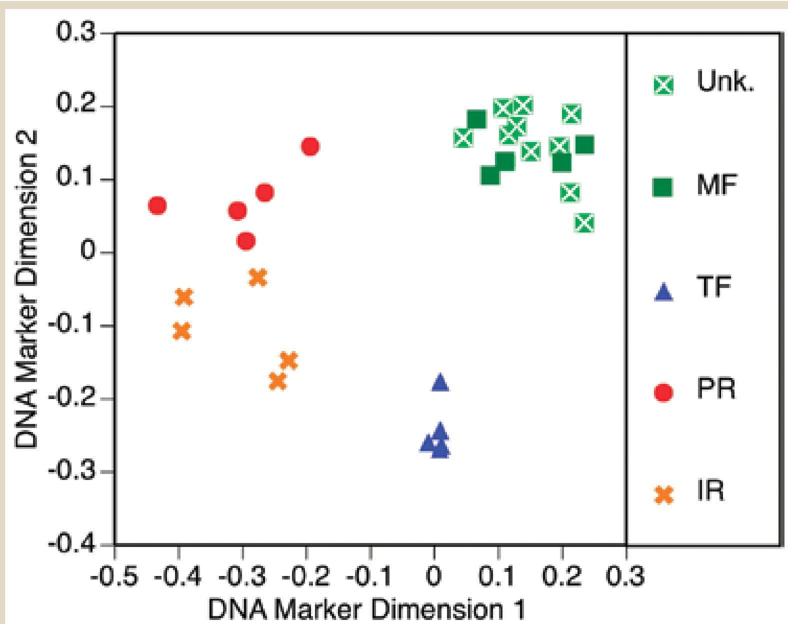

Figure 5. Two-dimensional plot of the DNA marker results separating the four species (MF = meadow fescue, TF = tall fescue, PR = perennial ryegrass, and IR = Italian ryegrass). The clustering of all 11 unknown (Unk.) samples from the Opitz farm with all meadow fescue control samples confirms their identity as meadow fescue.

[1]During the 1990s, Charles Opitz modified his grazing management from a relatively passive to a more aggressive system. He gradually increased the intensity and frequency of grazing events as he realized that his meadow fescue responded positively to the more aggressive management. Timely nitrogen fertilization was one of the underpinnings of this move to a more aggressive management system, ensuring that the meadow fescue would be capable of sufficient regrowth.

Figure 6. A healthy meadow fescue seedling that germinated and became established in a manure pat.

during the winter, his cattle spread viable seeds across hundreds of acres during the 1990s. Eventually, Opitz had nearly 1,000 acres of meadow fescue in nearly pure stands. There is a lot of evidence that grass seed can pass through the gut of a cow, retaining its viability and germinating in manure pats to form established plants (see Figure 6 for an illustration).

Because of the manner in which it was propagated, the Opitz meadow fescue represents a single population of plants. DNA research on these plants indicates that meadow fescue throughout the farm came from the original source—one or more patches of remnant oak savanna. Individual meadow fescue plants on the Opitz farm are long-term survivors, and many plants have crowns that are up to 6 inches in diameter. Numerous soil samples from the farm show that there is no meadow fescue seed bank that would have rejuvenated the stand with new seedlings. Using DNA markers to verify that neighboring plants are no more related to each other than distant plants, we further determined that established plants within the pasture are not producing new seeds to rejuvenate the stands. The Opitz meadow fescue is surviving on this farm by its own ability to withstand drought, freezing temperatures and grazing pressure. The lack of a seed bank is due to the intensive management of meadow fescue on the Opitz farm, seldom allowing it to go to seed.

Further research has identified meadow fescue on literally hundreds of farms in the Driftless (unglaciated) Region of southwestern Wisconsin, northwestern Illinois, northeastern Iowa and southeastern Minnesota. In this region, meadow fescue can be found in a wide range of habitats including bottomlands or uplands, deep or shallow soils, full sun or deep shade, and grazed or ungrazed conditions. Interviews with many landowners in this region have shown that meadow fescue pastures and hay fields in this region were not planted to improved varieties anytime in recent memory.

In nearly all cases within the Driftless Region, meadow fescue pastures occur on land that has been taken out of row crops and allowed to revert to "natural" pasture, or land that has been in some sort of pasture for many years. The experiences on the Opitz farm indicate that meadow fescue is opportunistic, particularly where grazing is managed intensively, but not too severely, and that it can naturally colonize many habitats within this region. In nearly every case, there are portions of remnant oak savanna either directly or indirectly adjacent to meadow fescue pastures. This leads to three theories about the introduction of meadow fescue to this region.

The primary immigration theory involves direct immigration of European settlers to the Driftless Region, bringing livestock and grass seed from the old country. Upon arrival and settlement in this region, their livestock would have rapidly degraded the understory of the oak savanna, which consisted largely of grasses and forbs that could not withstand moderate to intensive grazing pressure. This would have opened up the possibility of meadow fescue colonizing these degraded areas that could not be plowed.

The secondary immigration theory is very similar. It involves migration of farm families from the eastern USA to the Driftless Region, bringing livestock and seed on their travels. Meadow fescue first arrived in the northeastern USA, so this theory is highly plausible.

The summer/winter pasture theory is based on stories about land use in the Driftless Region after the mining industry gave way to livestock agriculture. In the late 1800s and early 1900s, the area was a principal summer

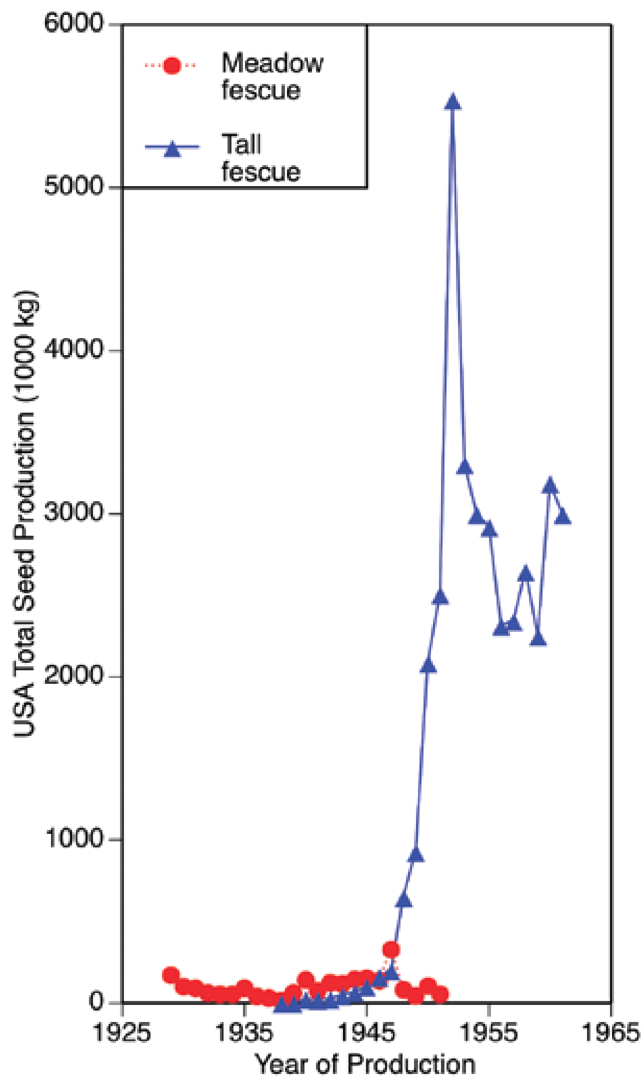

Figure 7. Total seed production in the USA for meadow fescue and tall fescue between 1929 and 1951.

pasturing region for livestock. Cattle were grazed in the southern USA in winter before being shipped on railroad cars to the Driftless Region, and likely other northern locations, for summer grazing. Because meadow fescue was fairly common throughout the eastern USA at this time, it is possible that the winter pastures in the southeast consisted of meadow fescue. In early spring, cattle could have been grazing pastures with ripe seed just prior to moving north, providing a simple mechanism for the migration and establishment of viable meadow fescue seeds into the pastures of the Driftless Region.

In Europe, there are three types of meadow fescue. They cannot be distinguished by eyesight. Each has a slightly different mutation in the DNA contained within its chloroplasts, which are the cellular organs that fix carbon from sunlight, water and carbon dioxide. Chloroplasts are inherited directly from mother plants, so they are rarely subject to mutations or chromosomal rearrangements, preserving unique mutations within regions for thousands of generations. The three mutations map to regions in Europe where meadow fescue survived the last glacial period about 11,000 years ago. These three areas were the Iberian Peninsula (Spain and Portugal), the Balkan Peninsula (Greece, Albania and the former Yugoslavia) and the Caucasus Mountains. Both the Iberian and Balkan populations are represented in the Driftless Region, suggesting that multiple introductions are responsible for the plants that we see today. In addition to multiple introduction events, multiple mechanisms of introduction are possible and quite likely.

Meadow fescue has been present in the USA since the early 1800s. Many agronomic trials of the early 1900s focused on simple comparisons of different species, including the recently introduced tall fescue and the old standby, meadow fescue. The transition zone between the northern and southern USA stretches from Missouri and Arkansas east to southern Virginia and the central Carolinas. Because tall fescue is so popular and frequent in this region, the area is sometimes called the “tall fescue belt.” Interest in tall fescue heightened as trial after trial showed consistently higher forage yields—by 10 percent or more—than meadow fescue and superior resistance to the crown rust disease. Meadow fescue held its own until the release of ‘Kentucky-31’ tall fescue in 1943. Within eight years, meadow fescue seed production was completely replaced by tall fescue (Figure 7). Essentially, meadow fescue was forgotten, not to reappear on the research scene until 1989.

Meadow fescue research

Research on meadow fescue was initiated shortly after the managed grazing movement of the 1980s gained momentum. With support from numerous graziers and the UW-Madison Center for Integrated Agricultural Systems (CIAS), we planted our first meadow fescue trials in 1990. Seven European varieties were included in a large trial that included a total of 91 varieties evaluated under managed grazing on three southern Wisconsin dairy farms.

The results confirmed what early agronomists had learned—tall fescue consistently yields more forage than meadow fescue. In our on-farm study, all of the tall fescue varieties provided more forage than all of the meadow fescues. However, the superior palatability of meadow fescue resulted in equal consumption of this fescue and tall fescue, despite the greater availability of tall fescue forage (Figure 8). As a direct result of this research, European companies showed increased interest in marketing meadow fescue varieties in the northern USA.

Shortly after the completion of this on-farm evaluation of fescue varieties, a meadow fescue breeding program was initiated at the University of Wisconsin. 'Azov' meadow fescue was the first variety produced by this program. It is a product of one cycle of selection for high forage availability under managed grazing. 'Hidden Valley' meadow fescue was later developed from plants collected on the Opitz farm.

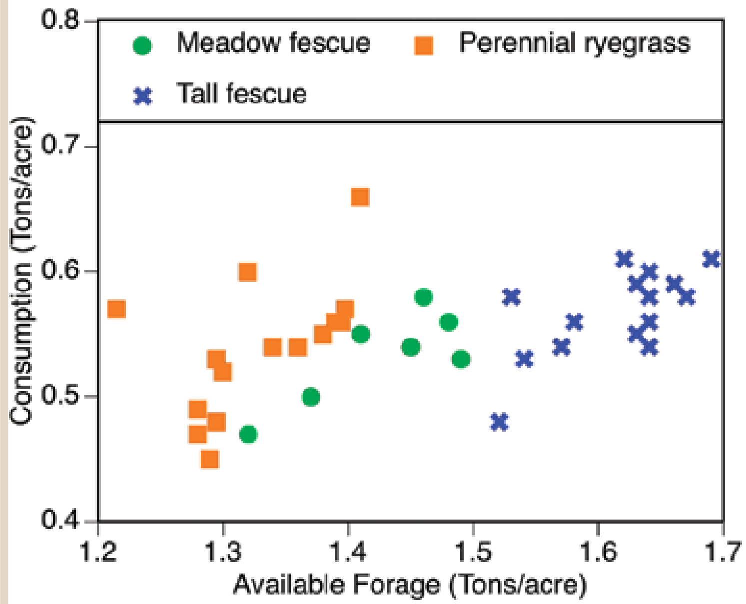

Figure 8. Relationship between consumption and available forage for meadow fescue, tall fescue and ryegrass varieties evaluated under managed grazing on three Wisconsin dairy farms. Source: Casler, M.D., D.J. Undersander, C. Fredericks, D.K. Combs, and J.D. Reed. 1998. "An on-farm test of perennial forage grass varieties under management intensive grazing." *J. Prod. Agric.* 11:92-99.

Table 1. Average forage yields (tons DM/acre) at Lancaster and Marshfield, Wisconsin in 2005 and 2006 under a six-cut management system Source: G.E. Brink, unpublished data.

	Lancaster			Marshfield	
Variety and species	**2005**	**2006**		**2005**	**2006**
'Barolex' tall fescue	1.95	2.15		1.51	1.45
'Bartura meadow' fescue	1.85	1.55		1.56	1.18
'Bronc' orchardgrass	2.09	1.96		1.50	1.55
'Hidden Valley' meadow fescue	1.89	1.74		1.54	1.35
'Azov' meadow fescue	2.10	1.71		1.65	1.29

LSD (5% error) for comparing varieties within columns = 0.12

Table 2. Average forage yields (tons DM/acre) under five nitrogen fertilization rates at Lancaster and Marshfield, Wisconsin in 2005 and 2006 under a six-cut management system. Source: G.E. Brink, unpublished data.

	Nitrogen fertilization rate (pounds N per cut per acre)				
Variety and species	**0**	**20**	**40**	**60**	**80**
'Barolex' tall fescue	0.87	1.23	1.81	2.30	2.61
'Bartura' meadow fescue	0.77	1.08	1.68	1.92	2.23
'Bronc' orchardgrass	0.79	1.37	1.91	2.22	2.58
'Hidden Valley' meadow fescue	0.75	1.25	1.69	2.00	2.41
'Azov' meadow fescue	0.91	1.38	1.78	2.06	2.31

LSD (5% error) for comparing varieties within columns = 0.15

Table 3. Average forage yields (tons DM/acre) at Lancaster and Marshfield, Wisconsin in 2005 and 2006 under a six-cut management system for two different cutting heights. Source: G.E. Brink, unpublished data.

	2005			2006	
Variety and species	**2" height**	**4" height**		**2" height**	**4" height**
'Barolex' tall fescue	2.59	1.95		3.01	2.26
'Bartura' meadow fescue	2.59	2.01		2.39	1.85
'Bronc' orchardgrass	2.69	2.10		2.82	2.28
'Hidden Valley' meadow fescue	2.69	2.02		2.42	2.00
'Azov' meadow fescue	2.74	2.20		2.63	1.96

LSD (5% error) for comparing varieties within columns = 0.17

Table 4. Average forage yields (tons DM/acre) at Lancaster and Marshfield, Wisconsin in 2005 and 2006 under a three-cut hay management system for two different cutting heights. Source: G.E. Brink, unpublished data.

	2005			2006	
Variety and species	**2" height**	**4" height**		**2" height**	**4" height**
'Barolex' tall fescue	3.30	2.52		4.02	2.78
'Bartura' meadow fescue	3.15	2.52		3.14	2.30
'Bronc' orchardgrass	3.27	2.62		3.47	2.96
'Hidden Valley' meadow fescue	3.16	2.75		3.04	2.42
'Azov' meadow fescue	3.56	2.77		3.19	2.56

LSD (5% error) for comparing varieties within columns = 0.28

Both of these varieties have been evaluated for forage yield under various management systems. When cut frequently—six times per year—'Hidden Valley' and 'Azov' meadow fescues yielded slightly less forage than both tall fescue and orchardgrass (Table 1, p. 7). Both 'Hidden Valley' and 'Azov' tended to yield more forage than 'Bartura' meadow fescue, a variety imported directly from Europe. Differences among the varieties and species were not always consistent, indicating that unknown environmental factors may favor one variety over another.

These differences were fairly consistent across nitrogen fertilization rates ranging from 0 to 80 pounds per acre (Table 2, p. 7). However, at higher rates of nitrogen application, there was a slight trend toward larger yield reductions in the meadow fescues. This may indicate that tall fescue and orchardgrass are better able to respond to nitrogen fertilizer.

Cutting height had a large effect on total forage availability, but did not generally change the ranking of the varieties (Table 3). Forage availability was greater with a 2-inch cutting height compared to a 4-inch cutting height. The varieties had similar forage yields in 2005, but the meadow fescues had lower yields than tall fescue and orchardgrass in 2006. The results were similar when the varieties were managed under a 3-cut system (Table 4), but there was a greater reduction in forage yield of the meadow fescues compared to tall fescue and orchardgrass. Meadow fescue is well suited to frequent, managed grazing, but not as well suited as taller grasses to hay management systems.

'Azov' meadow fescue consistently yielded more forage than 'Hidden Valley'. This was likely due to the intensive selection for high forage yield under managed grazing during the development of this variety. This encouraging result suggests that we can continue to increase the forage yield potential of meadow fescue varieties through breeding. Both 'Hidden Valley' and 'Azov' meadow fescue are currently in the seed multiplication phase prior to their release and public distribution.

One of the most important traits of meadow fescue is its high feed quality. Our research on three meadow fescue

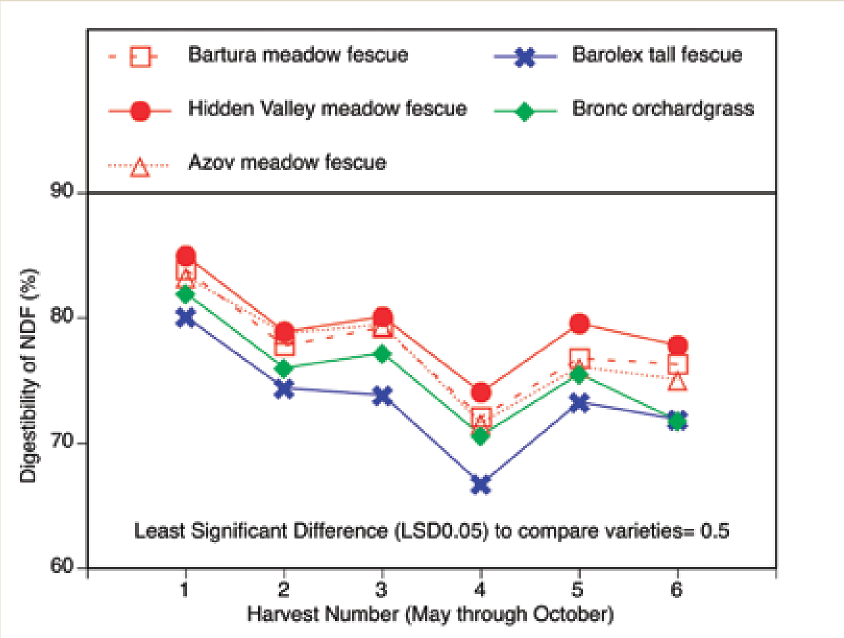

Figure 9. Digestibility of neutral detergent fiber (NDF) for three meadow fescue varieties, one soft-leaf tall fescue variety, and one orchardgrass variety harvested six times per year when the canopy was approximately 10-12 inches high. Results are presented as averages for Lancaster and Marshfield, Wisconsin in 2005 and 2006.

varieties shows them to be consistently higher in digestibility of NDF (neutral detergent fiber) than soft-leaf 'Barolex' tall fescue and 'Bronc' orchardgrass throughout the growing season (Figure 9). Higher NDF digestibility leads to increased animal production and may be partly responsible for the observations that meadow fescue is highly palatable to grazing livestock.

The meadow fescue endophyte

'Hidden Valley' meadow fescue, like most meadow fescue plants collected from old pastures in the Driftless Region, contains a naturally occurring endophyte. While tall fescue endophytes produce both protective (loline) and harmful (ergovaline) alkaloids, the meadow fescue endophyte (*Neotyphodium uncinatum*) produces only the protective alkaloids that contribute to heat and drought tolerance. Because of this, meadow fescue shows none of the detrimental effects on livestock that can be caused by other fescues. Laboratory tests of 'Hidden Valley' and other meadow fescues collected from the Driftless Region confirm that these plants do not produce the detrimental ergovaline alkaloids. Because meadow fescue cannot be infected by the tall fescue endophytes, there is no known mechanism for meadow fescue to cause the types of livestock disorders that have been observed from grazing endophyte-infected tall fescue.

The North American meadow fescue enigma

European populations of meadow fescue contain variable amounts of endophyte, ranging from relatively low to nearly 100 percent infection rates. European grassland scientists have long considered meadow fescue to be a relatively non-competitive species. There are many published studies and anecdotes describing how meadow fescue tends to die out in the face of competition from companion grasses such as perennial ryegrass and orchardgrass. In addition, there are numerous reports that meadow fescue is not considered a shade-tolerant grass in Europe. Finally, as global temperatures have steadily increased during the late 20th and early 21st centuries, there have been consistent observations that meadow fescue is dying out at an alarmingly rapid rate at lower altitudes of southern European mountain ranges. It appears that rising global temperatures are reducing the range of native European meadow fescue populations, restricting it to higher altitudes and more northern latitudes.

These reports directly contrast with our observations of meadow fescue in the Driftless Region during the same time period, with the same trend toward elevated average temperatures. Meadow fescue populations have rapidly increased in frequency and dominance in the Driftless Region. There are many examples of healthy meadow fescue populations that have formed dense monocultures in pastures that were once dominated by other species. Meadow fescue populations from the Driftless Region are clearly cold tolerant, as evidenced by long-term survival on the Opitz farm. Anecdotal evidence also points to superior drought tolerance on the extremely shallow and drought-prone soils of the Driftless Region. In addition, meadow fescue populations grow in the deep, consistent shade of remnant oak savannas throughout this region.

Why are these North American populations of meadow fescue becoming more dominant and well adapted while some native European populations are gradually dying out? We don't yet know the answer to this question, but it might relate to two factors. So far, every plant we have tested from the Driftless Region is infected with an endophyte. It is very possible that these plants have a special endophyte that helps protect them from stresses associated with extreme climatic conditions. The other factor may have to do with the host plant's DNA. We think that these meadow fescue populations have resided in this region for over 100 years, which is enough time for the populations to adapt by survival of the best adapted plants and mortality of those plants less tolerant of local conditions. Future research will be aimed at answering this question, in addition to determining the suitability of Driftless meadow fescue populations for other parts of North America.

Tall fescue

Ask any Wisconsin farmer or extension agent about tall fescue; he or she will tell you that livestock prefer not to eat this grass, and if they do eat it their health or performance may suffer. Research has shed light on some of the mysteries that surround tall fescue. Now it can be considered a viable, and perhaps preferred, pasture plant for high-producing livestock in the North.

Some history

Tall fescue, grown on more than 35 million acres, is the most important cultivated pasture grass in the USA (Figure 10). It was introduced from Europe sometime in the 1800s. While the exact date and details of this introduction are unknown, tall fescue may have arrived as a contaminant in meadow fescue seed imported from England. Whatever the circumstances of its Wisconsin debut, it is not widely grown here.

Tall fescue received little attention as a pasture crop until the 1940s, when the variety 'Alta' was released in Oregon and the variety 'Kentucky 31' was released in Kentucky. In the southeastern states, tall fescue was rapidly recognized for its dependability on a wide range of soil types and ability to provide forage most of the year. Tall fescue filled a void that no other cool season pasture grass could fill, and it soon became the dominant cool-season grass in pastures of the southeastern USA.

Figure 10. 'Select' endophyte-free tall fescue growing with Kura clover.

Fescue toxicity

By 1950, it was widely recognized that livestock grazing tall fescue were prone to health problems that often resulted in poor animal performance. The term "fescue toxicosis" was applied to three syndromes observed in livestock that grazed tall fescue. The first of these, **fescue foot**, is a situation where gangrene results in lameness and sometimes loss of hooves, tails and ears. The second, **fat necrosis**, is the accumulation of hard fat in the abdominal cavity causing digestive problems and difficult births. The third, **summer syndrome**, is a chronic condition characterized by failure to shed the winter hair coat, heat intolerance, depressed feed intake and reduced rates of milk and meat production. Despite these problems, tall fescue became the dominant cool-season grass in southeastern USA pastures because of its superior persistence and yield potential in that environment. The related health problems were tolerated because other suitable grasses were not available.

Farmers in Wisconsin and other northern states are able to grow cool-season grasses such as smooth bromegrass and orchardgrass, so the problematic tall fescue was not widely sown here. Where tall fescue was introduced in Wisconsin, it was found to be less palatable than most other grasses. It frequently set seed because it wasn't grazed, creating increasingly large patches of unpalatable forage in pastures. Between the animal health problems

Table 5. Decline in animal performance on a diet of high endophyte tall fescue (61 to 100% infected) and a control diet of low endophyte tall fescue (0 to 8% infected plants)

Research location	Class of livestock	Change in animal performance (relative to control)
Alabama	Steers	-0.84 lb beef/day
Arkansas	Steers	-0.44 lb beef/day
Georgia	Steers	-0.29 lb beef/day
Kentucky	Steers	-0.55 lb beef/day
Mississippi	Steers	-0.48 lb beef/day
Missouri	Steers	-0.90 lb beef/day
Oklahoma	Steers	-0.51 lb beef/day
Texas	Steers	-1.12 lb beef/day
Tennessee	Steers	-0.42 lb beef/day
Virginia	Steers	-0.53 lb beef/day
Kentucky	Dairy cows	-16.94 lb milk/day

Adapted from Roberts, C., and Andrae, J. 2004. Tall fescue toxicosis and management. Online. Crop Management doi:10.1094/CM-2004-0427-01-MG.

seen in the South and the observation that cows preferred other grasses, tall fescue was avoided by Wisconsin farmers. Furthermore, research and extension programs were directed to safer bets than tall fescue.

What causes fescue toxicosis?

The cause and management of tall fescue-induced livestock health and performance problems remained a mystery until the mid-1970s. At this time, animal scientist Joe Robbins observed cattle on two tall fescue pastures in Georgia and noted that one herd suffered from fescue toxicity, while the other herd was healthy. He studied the tall fescue plants and discovered that the toxic pasture was 100 percent infected with an endophyte that produced ergovaline alkaloids known to cause animal health problems. A few years later, agronomist Carl Hoveland in Alabama provided final confirmation that this fungal endophyte was causing toxicosis. Steer average daily gain was 66 percent greater and gain per acre 28 percent greater on endophyte-free tall fescue pastures. Results from a large number of livestock grazing and feeding trials revealed that both meat and milk production are reduced in cattle consuming endophyte-infected tall fescue (Table 5). The presence of the fungal endophyte, however does not affect crude protein, digestibility, fiber and mineral concentrations in tall fescue.

It was soon discovered that a mutualistic relationship exists between the fungus *Neotyphodium coenophialum* and tall fescue that was important for its production in the South. Tall fescue does not persist or yield well there-without endophyte infection. The endophyte receives nutrients and a favorable environment in which to live, reproduce and disseminate from the host grass. The grass benefits from improved tolerance to insects, diseases, nematodes and drought. These benefits are imparted by the beneficial loline alkaloid in the endophyte.

Solving the problem of fescue toxicosis

While it was the right decision to avoid widespread use of tall fescue in Wisconsin in the past, it is now clear that removal of the fungal endophyte solves the problem of tall fescue toxicosis. The endophyte can be largely removed from infected seed by storing it at ambient temperatures (at least 75°F) for 12 to 18 months. Seedlings established from endophyte-free seeds will not be infected with the endophyte, and natural infection of these plants in the field is extremely unlikely. Seed produced from endophyte-free plants is also free of this fungus. Endophyte-free seed is readily available on the market and should be used in Wisconsin.

Removing the fungal endophyte makes sense for northern climates. But it doesn't work in the southern

USA, where the endophyte allows fescue to thrive. Recent research has identified strains of the endophyte species found in tall fescue that are non-toxic (low in ergovalines and animal friendly) to livestock but still provide all of the benefits to the plant in stressful environments. In the southern USA, planting tall fescue infected with non-toxic MaxQ or ArkPlus endophytes is the surest way of eliminating animal losses from toxicosis while maintaining the benefits of the endophyte.

We have observed no effect of fungal endophytes in either toxic or animal-friendly forms on persistence or yield of tall fescue in Wisconsin. Cooler air and soil temperatures, favorable rainfall distribution through the growing season and fewer pests that are detrimental to tall fescue are likely reasons that this forage does not benefit from the presence of fungal endophyte here. Adding MaxQ or ArkPlus animal-friendly endophytes unnecessarily increases seed costs in Wisconsin and other northern environments. Endophyte-free varieties of tall fescue will avoid the toxicosis issues and should have good survival if they have performed well in local variety trials.

How about palatability?

Published data demonstrate that endophyte-free tall fescue is more palatable than fungus-infected tall fescue when cattle are only offered this forage. However, when cattle have a choice of fungus-free tall fescue or another grass, they frequently avoid the tall fescue until last. Wisconsin variety trials of grazed forages clearly demonstrate that cattle prefer grasses other than tall fescue, when offered a choice. So the fungal endophyte is not the only factor limiting the palatability of tall fescue. Older varieties of tall fescue, like 'Kentucky 31' and 'Fawn', have stiff leaves with numerous barb-like projections on the edges. These characteristics are thought to contribute to the palatability problem. New varieties with softer leaves that are free of barbs are currently on the market and are reportedly more palatable. There are no published data that document improvements in palatability of these new "soft-leaf tall fescue" varieties, but unpublished observations from Georgia, Kentucky, Wisconsin and New Zealand suggest that some of them are indeed more palatable.

Agronomic performance in Wisconsin

When managed for hay or pasture, tall fescue is among the highest yielding perennial grasses grown in Wisconsin (Table 6). The greatest yield advantage usually occurs in mid-summer and autumn, when the productivity of other grass species tends to slump. Laboratory measures of forage quality including crude protein, fiber and digestibility are no better or no worse than other grasses, so greater yield should equate to greater per-acre meat or milk production.

Table 6. Grass performance at Arlington and Marshfield, Wisconsin over four years. Establishment year data are not included in the means.

Forage crop[1]	Arlington	Marshfield
	tons/acre	
'Fawn' tall fescue + N	5.2	4.0
'Vulcan' tall fescue + N	5.1	3.8
'Crown' orchardgrass +N	4.5	3.3
'Venture' reed canarygrass + N	4.1	3.1
'Alpha' Smooth bromegrass + N	3.5	3.0
'Fawn' plus 'Endura' kura clover	4.0	3.3
'Vulcan' plus 'Endura'	3.9	3.1
'Fawn' plus 'Endura' + N	5.1	3.9
LSD (0.05)	0.4	0.4

[1]Monoculture grasses received 200 pounds of nitrogen fertilizer per year in four applications. Only one of the tall fescue-clover mixtures received nitrogen fertilizer.

Tall fescue fertilized with nitrogen usually yields more than grass grown with a legume and no nitrogen fertilizer (Table 6). In pastures where the nitrogen in manure is returned to the sward, these differences are not as great. Growing tall fescue with

Table 7. Pasture composition, dry matter intake and milk production from binary mixtures of tall fescue, reed canarygrass and Kentucky bluegrass with kura clover at Arlington, Wisconsin.

	Pasture Treatment[1]		
	Tall fescue[2]/ kura clover	Kentucky bluegrass/ kura clover	Reed canarygrass/ kura clover
Pasture offered, grass:legume	55:45	25:75	63:37
Pasture eaten, grass:legume	56:44	41:59	34:66
Pasture intake, lb DM/d	38.4	39.5	25.6
Milk yield/cow, lb/d	60.0	64.1	60

[1]In addition, cows were offered 12 lb/d of grain concentrate.
[2]The tall fescue was 'Select', a stiff-leaf, endophyte-free variety.

Table 8. Steer gains per acre on pastures of orchardgrass, tall fescue or tall fescue in mixture with kura clover at Arlington, Wisconsin. Values are means over 3 years.

Pasture treatment	Steer gain/acre (lb/a)
'Orion' orchardgrass	560
'Select' tall fescue[1]	700
'Vulcan' tall fescue[1]	670
'Vulcan' tall fescue + 'Endura' kura clover[2]	765

[1]Both tall fescue varieties are endophyte free. Select is a stiff-leaf variety and Vulcan is a soft-leaf variety.
[2]Kura clover made up approximately 50% of this mixture averaged over seasons and years.

a legume offers many benefits, however, despite yielding less than nitrogen fertilization. Higher forage yields don't necessarily translate into higher milk and beef production, either. For all grasses, including a high-yielding, persistent legume in the pasture can result in significant savings with little to no N fertilization needed. Grass-legume mixtures usually contain more crude protein and less fiber than grass alone. This improvement in feeding value usually results in greater average daily gains in beef animals and greater milk production per day in dairy cows.

Winter persistence of different tall fescue varieties is obviously an important consideration in Wisconsin and other northern states. We currently do not have comprehensive data on winter survival of tall fescue varieties (or other grasses, for that matter), and this makes it difficult to identify the best variety for Wisconsin. The issue of winter survival becomes even more important when selecting soft-leaf tall fescue varieties, as they show very different degrees of winter persistence. There are currently several soft-leaf and stiff-leaf tall fescue varieties that survive northern winters extremely well. Producers are encouraged to visit with reputable seed company representatives and check online variety trial information from northern states.

Livestock performance on tall fescue pasture

Forage intake and milk production on tall fescue-clover pastures, compared to other grasses with clover, were studied at the UW-Madison Arlington Agricultural Research Station. Dairy cattle readily grazed endophyte-free 'Select' tall fescue mixed with kura clover (Table 7). Cattle did not show a preference for or against tall fescue grown in a grass:legume proportion of 55:45. The long-held tenet that livestock will avoid grazing tall fescue did not hold in this research with lactating dairy cows. Intake of 38.4 lb dry matter/day of the tall fescue-kura clover mixture was excellent considering that the cattle also received 12 lb/day of grain in the barn at milking, and compared favorably with other grasses in the experiment. Milk production was similar among all pasture treatments, indicating that there should be no concern about pasture intake or milk production by dairy cattle on endophyte-free tall fescue.

Orchardgrass is one of the more popular grasses for major pasture renovation in Wisconsin. In a research

Figure 11. A group of steers graze soft-leaf tall fescue and kura clover at the UW-Madison Arlington Research Station.

project conducted from 2005 through 2007 at the UW-Madison Arlington Agricultural Research Station, beef steers gained approximately 22 percent more weight per acre on tall fescue compared to orchardgrass pastures (Figure 11). This was associated primarily with the greater yield potential and seasonal yield distribution of tall fescue (Table 8, page 13). Adding kura clover to tall fescue resulted in similar gains per acre as tall fescue that received 100 lb per acre of nitrogen fertilizer. The high level of beef cattle productivity observed on tall fescue alone or in mixture with clover is a result of the combination of superior yield potential and high forage quality compared to orchardgrass.

Is tall fescue an option for Wisconsin pastures?
Tall fescue certainly deserves greater consideration for pastures in northern states than it has received in the past. It is the highest yielding pasture grass in Wisconsin. Some varieties have excellent persistence, and livestock performance on tall fescue is similar to or better than other grasses more commonly grown in the state. Tall fescue and perennial ryegrass offer similar grazing management flexibility. Tall fescue is not as sensitive to the timing of grazing as smooth bromegrass, timothy and reed canarygrass, and does not get as rank as orchardgrass in the late spring. Recent research has demonstrated that both dairy and beef cattle perform well on endophyte-free tall fescue. Still, the reputation of this grass as being unpalatable and toxic will cause many farmers to proceed with caution. Stay tuned to CIAS and UW-Extension for updates on tall fescue performance in Wisconsin.

Festulolium

Festuloliums are hybrids of ryegrasses and fescues (Figure 12). There are a few known instances of crosses between ryegrasses and fescues occurring in nature, but most of these crosses have been made by plant breeders using highly technical methods. Much of this work began in the 1950s in Europe, resulting in a large number of European varieties that were common in the 1960s and 1970s.

Once ryegrass-fescue hybrids were developed, plant breeders intensively selected plants with desirable appearance and traits. In Europe, hybrids were selected for the appearance of ryegrass combined with the winter hardiness, heat tolerance and drought tolerance seen in fescue. These breeders selected plants that had the physical appearance of ryegrasses, but with better stress tolerance that reflected some of the genes transferred from fescue. Research has shown that approximately 70-90 percent of the DNA of these European festulolium varieties is from ryegrass. This research has also verified that small bits of fescue chromosomes were successfully transferred into plants that mostly resemble ryegrass.

Figure 12. Festulolium is a hybrid of ryegrass and fescue.

Table 9. Survival of 'Spring Green' festulolium compared to its two major parents after three weeks at 12º F in a cold chamber or two winters at 10 field locations. Source: Casler, M.D. and others. 2002. "Natural selection for survival improves freezing tolerance, forage yield, and persistence in festulolium." *Crop Science* 42:1421-1426.

Variety	Percentage survival after 3 weeks at 12º F	Percentage survival in Hardiness Zones 2-4	Percentage survival in Hardiness Zones 5-6
'Kemal'	3	39	82
'Tandem'	33	34	77
'Spring Green'	58	51	80
LSD (0.05)	10	6	6

Hardiness Zones 2-4: Arlington, Ashland, Lancaster, Marshfield, WI; Rosemount, MN.
Hardiness Zones 5-6: Ames, IA; Ithaca, NY; Lexington, KY; Rock Springs, PA; Wooster, OH.

In the USA, the opposite approach was used. Plant breeders aimed to transfer the superior palatability and digestibility of ryegrass into tall fescue. The tall fescue variety 'Kenhy' is derived from fescue-ryegrass hybrids that were selected for their tall fescue appearance combined with improved forage quality.

Because the genes transferred into either ryegrass or fescue represent a small proportion of the DNA in the new plants, the traits that are transferred from the donor parent are not fully expressed. For example, the forage quality of 'Kenhy' may be a bit better than 100 percent tall fescue varieties, but it's not nearly as good as that of the ryegrass that contributed a few genes to this variety. Likewise, meadow fescue contributed drought tolerance and winter hardiness genes to many festulolium varieties in Europe, but these varieties are only slightly better than perennial ryegrass when it comes to these traits.

Because most festulolium varieties were bred in regions of Europe where ryegrasses are generally well adapted, they do not survive under the harshest winter conditions in the northern USA. In the late 1980s, we evaluated a number of festulolium varieties for winter survival at several Wisconsin locations. After several harsh winters, we selected surviving plants from several locations of research trials and one intensively grazed pasture.

The 'Spring Green' variety is the product of these selections. This variety has been quite successful, even though its improvement resulted in only a small increase in winter survival. The plants that survived under harsh winter conditions had superior freezing tolerance compared to the parents of 'Spring Green' (Table 9). This translated to increased survival at locations in USDA Hardiness Zones 2 through 4, while there was no difference in survival at locations in Hardiness Zones 5 and 6 with milder winter climates.

Conclusions

As fescues continue to move into grazing operations in the northern USA, interest in and local knowledge of their culture and management continue to increase. Seed companies have responded to this increased demand by making additional varieties available to a wider range of producers within this region. Tall fescue, meadow fescue and festulolium all appear to have value in grazing operations in the northern USA, depending on climate, grazing management and personal preferences. Meadow fescue is the most cold tolerant of these grasses, with very high forage quality and relatively high drought tolerance. Tall fescue has the highest forage yield potential (particularly in the mid-summer), good forage quality (for soft-leaf varieties) and excellent drought tolerance. Festulolium has very high forage quality and good summer production, but has greatest value in multiple-species mixtures because of its relatively low cold tolerance. Forage fescues indeed have a bright future in managed grazing systems in the northern USA.