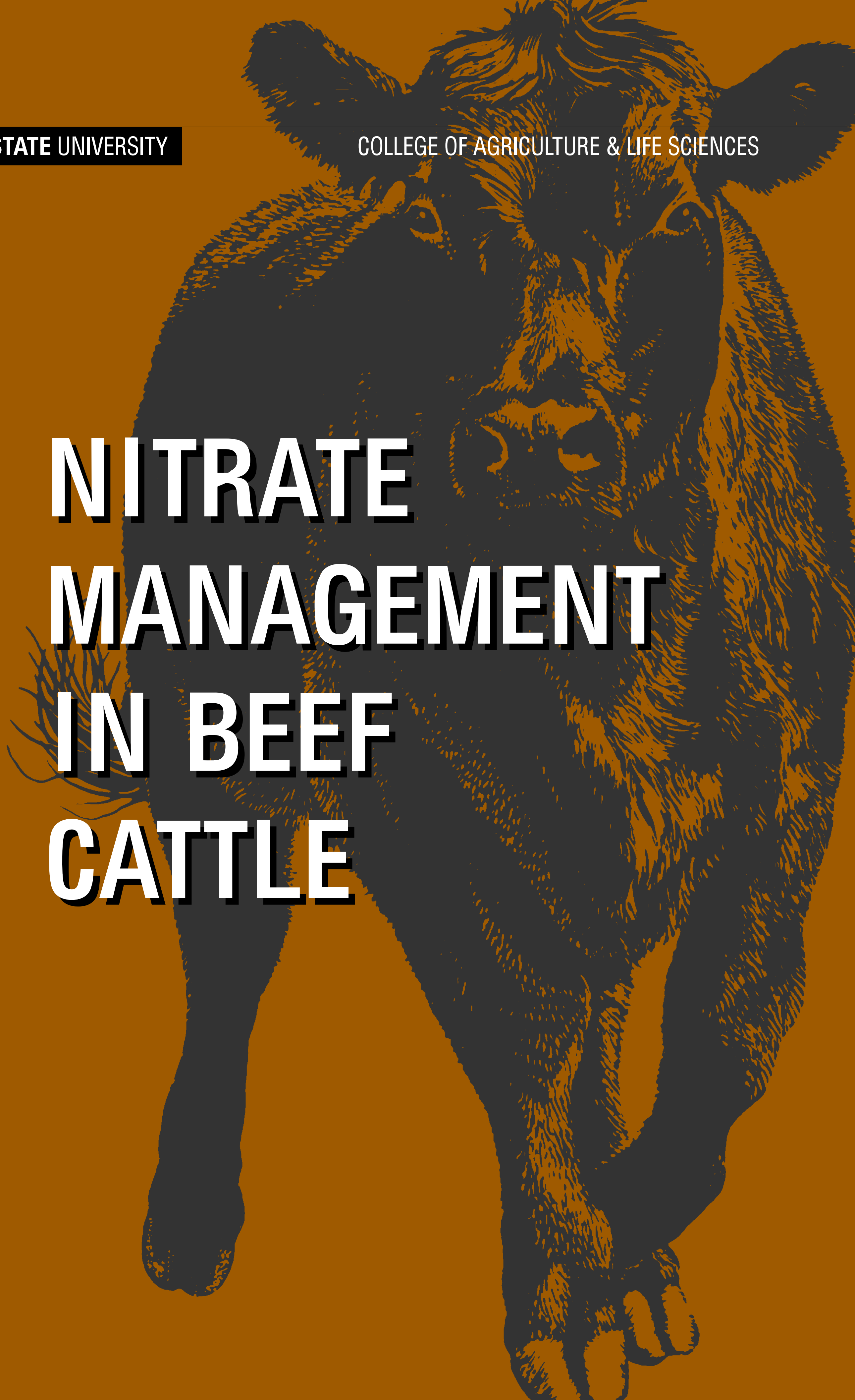
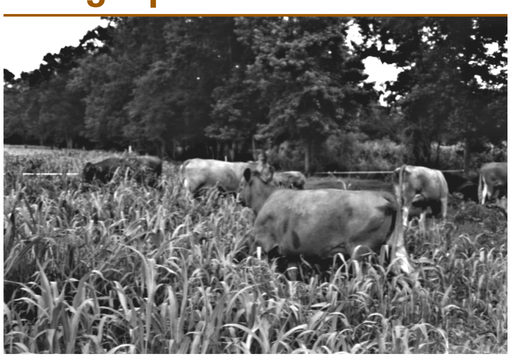
NC STATE UNIVERSITY
COLLEGE OF AGRICULTURE & LIFE SCIENCES

NITRATE MANAGEMENT IN BEEF CATTLE



Nitrate poisoning, which can kill beef cattle within a matter of hours, is on the rise in North Carolina. Beef producers should learn how to prevent nitrate from accumulating in forage plants. If producers must feed high-nitrate forages, they can take steps to limit the risk of the economically devastating losses associated with acute nitrate poisoning. Hay producers also should learn how to manage nitrogen to avoid liability resulting from the sale of potentially toxic, high-nitrate hay.

Nitrate accumulation in forage plants



Nitrate can reach toxic levels in forages any time the nitrogen supply in the soil exceeds the nitrogen needs of the plant. Plants absorb nitrogen from the soil in the form of nitrate, which is later converted to protein. When nitrate is available to the plant but protein synthesis is slow, nitrate accumulates, especially in the lower part of the plant, until protein synthesis increases. Anything that slows plant growth can lead to increased nitrate levels in well-fertilized plants. This could include drought, long periods of cloudy or cool weather, or herbicide applications.

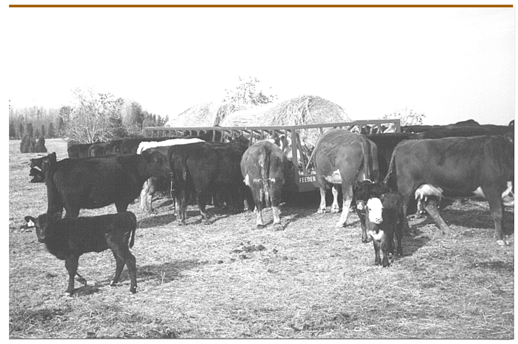
Some plants are called "nitrate accumulators" (Table 1) because they often accumulate toxic levels of nitrate during drought conditions even when soil nitrogen levels are moderate. These nitrate accumulators include summer annuals (millet and sorghum x sudangrass hybrids), johnsongrass, and annual weeds such as pigweed and lambsquarters. Other forage plants like bermudagrass, fescue, orchardgrass, small grains, and ryegrass accumulate nitrate only when high levels of nitrogen fertilizer are applied.

TABLE 1. ACCUMULATOR AND NON-ACCUMULATOR PLANTS

ACCUMULATORS	NON-ACCUMULATORS
Johnsongrass	Bermudagrass
Pearl millet	Fescue
Lambsquarters	Orchardgrass
Pigweed	Small grains
Sorghum x sudangrass hybrids	Ryegrass
	Legumes

In the past, concern over nitrate poisoning mostly focused on nitrate accumulators. However, in recent years excessively high nitrate levels have become common in bermudagrass and fescue due to the large amounts of animal wastes (and in some cases commercial fertilizers) being applied to pasture and hayland.

Nitrate toxicity in cattle



Nitrate itself is not toxic to cattle. However, in unadapted animals, nitrate is converted into nitrite in the rumen and absorbed into the bloodstream. Nitrite interacts with oxygen-carrying hemoglobin in red blood cells, which leads to the formation of methemoglobin, and that reduces the ability of the blood to transport oxygen. Blood that is high in methemoglobin is chocolate brown, a sight sometimes observed in cattle suffering from acute nitrate toxicity.

The most common sign of acute nitrate poisoning is sudden death of one or more animals that appeared healthy the previous time they were observed. Early signs of acute nitrate toxicity can be seen within 6 to 8 hours after ingestion of a large amount of nitrate. They include labored breathing, frothing at the mouth, frequent urination, diarrhea, staggering, and a brown cast to the mucous membranes. Collapse, convulsions, and death usually follow within 30 minutes of the onset of symptoms. Less noticeable signs may be a low calving rate (due to abortions) and in some cases reduced weight gain in growing cattle. Producers should test forage and employ other management strategies to prevent cattle deaths and minimize the more subtle problems.

Significant cattle deaths most commonly occur when a producer feeds high-nitrate forages to hungry cattle that are not adapted to nitrate. Every fall, reports of cattle deaths increase at the start of the winter feeding period. In this scenario, cattle have been allowed to graze a pasture until there is little or no forage remaining and the animals are hungry. They are then fed round bales and rapidly eat a large amount from one section of a bale. If the hay is high in nitrate, and especially if a portion of the bale is exceptionally high, death of some animals is likely. Most producers have several cuttings of hay on hand, and knowing the nitrate levels will allow them to use the hay with the lowest nitrate level at the start of the feeding period.

Cattle deaths also commonly occur when the animals are turned into summer annuals shortly after a drought. When plants receive sufficient moisture, they can take up nitrate very rapidly. After a drought, however, the growth of the plant, and therefore the protein synthesis that uses the nitrates, resumes more slowly. After droughts, producers want to get back to grazing as soon as possible and often turn out hungry cattle when nitrate levels are at their highest. Allowing 2 weeks of forage growth after a drought and before grazing will minimize problems. Providing plenty of low-nitrate hay for the animals to fill up on before allowing them to resume grazing on drought-affected forage is another strategy for reducing the risk of toxicity.

Treatment of nitrate toxicity

The first step in treating a suspected outbreak of nitrate poisoning is to immediately separate cattle from potentially toxic forages to reduce the risk of additional poisoning. You should contact your veterinarian immediately for diagnosis and assistance in handling cases of suspected nitrate toxicity.

Methylene blue has long been used as an antidote for nitrate toxicity. Methylene blue converts methemoglobin (caused by nitrite) to hemoglobin, thus restoring the oxygen-carrying capacity of the blood. Unfortunately, methylene blue is a mutagen and a suspected carcinogen, which raises human health concerns associated with its use in food animals. It also transfers readily to milk, making its use in lactating dairy cattle a serious concern. Because of these problems, methylene blue is not approved by the U.S. Food and Drug Administration (FDA) for treating animals suffering from nitrate toxicity.

Due to the rapid onset of symptoms, often with sudden death before treatment can be administered, and the lack of an approved antidote, prevention is the key to managing nitrates in cattle. If producers expect the possibility of nitrate toxicity in their herd, they should work closely with their veterinarian so they understand the best approaches for preventing and treating cases.

Preventing nitrate accumulation in forages

Nitrogen should be applied to a crop at appropriate agronomic rates. This means that crops should not receive more nitrogen than they can efficiently take up. In dry years, crops need less nitrogen than during wet years simply because drought-stressed plants produce lower yields. In dry years, nitrogen rates should be lower to account for the lower yield, and this can be accomplished by skipping an application or increasing the interval between applications. Most non-leguminous hay crops can use no more than 40 to 50 pounds of nitrogen per ton of yield. In grazing systems, much of the nitrogen consumed is returned to the soil in manure and urine, which means that only 20 to 25 pounds of supplemental nitrogen per ton of forage may be needed.

If nitrate levels are consistently high under normal conditions (above 0.25 percent nitrate ion) in non-accumulator plants such as bermudagrass, too much nitrogen is being applied to the soil, and annual nitrogen application rates should be reduced. Not only does the elevated forage nitrate in non-accumulator species pose a threat to the health of cattle, it also suggests that excessive nitrogen may be leaching to shallow groundwater, some of which could eventually enter surface waters. High nitrate levels in non-accumulator species may be the result of using forage crops as receivers for waste nitrogen, in which case application rates are likely to be very high. This is in contrast to the use of commercial nitrogen sources, in which case the high cost of nitrogen likely will result in growers applying it at more moderate rates.

When applying nitrogen or harvesting forage, producers should consider environmental conditions such as drought, cloudy weather, and time of day. Nitrogen fertilizer should not be applied during very dry weather, especially if nitrogen was applied earlier in the season. Wait several weeks after soil moisture is adequate before cutting forage for hay following a drought. Ensiling the crop, rather than harvesting it as hay, will reduce nitrate somewhat; therefore if producers can, they should ensile crops they suspect to be high in nitrate.

Producers should understand clearly which plants are nitrate accumulators and which are not (Table 1). Extreme caution should be employed when turning cattle into fields that are infested with weeds that are known nitrate accumulators or when letting them graze summer annuals during and shortly following drought stress. Producers with primarily non-accumulator species in their fields have little to fear from nitrate toxicity as long as they do not apply too much nitrogen fertilizer.

Feeding management of high-nitrate forages

The first step in managing high-nitrate forages is to have a good testing program, which requires collecting a representative sample of forage. At least 20 percent, or at least 20 bales, from each cutting of hay should be sampled whether they are square or round bales. A "cutting" should represent hay that comes from the same field, is cut at the same time, and is grown with similar management practices. The samples should be taken with a core sampler rather than by pulling hay from a bale, which may produce misleading results due to uneven distribution of high-nitrate forage within or between bales. If the analysis shows that nitrate is high in a given cutting of hay, the producer may desire to sample bales individually, although this is not practical or necessary in most situations. Hay from different areas of a field can differ in nitrate level, especially if the fertilization rate was not uniform, so producers should decide whether to sample individual bales based on knowledge about their own situation.

When obtaining pasture samples, walk in a random, zigzag pattern over the whole field and hand pluck a small area down to grazing height from about 20 locations. This process is similar to obtaining a soil sample.

Nitrate testing services

Most state labs and commercial labs will analyze forages for nitrate. The North Carolina Department of Agriculture and Consumer Services (NCDA&CS) Forage Testing Lab will, upon request, analyze forage for nitrate or add nitrate testing to standard forage quality analysis at no extra charge. The North Carolina lab also will notify producers immediately when it finds high nitrate levels. Commercial labs usually add a small charge for nitrate analysis.

Understanding lab results

Labs vary in the way they report nitrate levels. The two most common approaches are to report nitrate ion levels (percentage nitrate) or to report nitrate-nitrogen in parts per million (ppm). The NCDA&CS lab reports nitrate ion levels as percentages. Table 2 shows management considerations for high nitrate forage expressed either as percentage nitrate ion or ppm nitrate-nitrogen. Some labs also report nitrate ion in ppm, or nitrate-nitrogen as a percentage, so it is important to know how to convert one to the other. To convert percentage to ppm, multiply by 10,000; to convert from ppm to percentage, divide by 10,000. For example if the result is reported as 0.35 percent nitrate-nitrogen, convert to ppm as follows: 0.35 x 10,000 = 3,500 ppm nitrate-nitrogen. If the result is reported as 8,000 ppm nitrate ion, convert to percentage nitrate ion as follows: 8,000/10,000 = 0.8 percent nitrate ion.

In a poisoning case that occurred in North Carolina in the winter of 1993-94, cows were fed round bales of a sorghum x sudangrass hybrid. There had been several short dry spells the previous summer, and the producer had cut the forage several times and stacked it around the edge of the field with no knowledge of the potential for nitrate toxicity. When feeding began, the producer offered the cows several bales of hay and, overnight, several cows died. Nitrate poisoning was diagnosed, and testing of the various forages available revealed that the sorghum x sudangrass had an average of 1.78 percent nitrate ion.

TABLE 2. MANAGEMENT CONSIDERATIONS FOR USE IN FEEDING FORAGES WITH VARIOUS LEVELS OF NITRATE

LEVEL IN FORAGE (DRY BASIS)		FEEDING PRECAUTIONS	
NITRATE ION[1] %	NITRATE NITROGEN PPM	UNADAPTED ANIMALS	ADAPTED ANIMALS[2]
0.0 - 0.25	0 - 568	**Safe:** Generally considered safe for all animals.	**Safe**
0.26 - 0.50	569 - 1,136	**Slight risk:** Should not make up more than 50 percent of total intake for pregnant animals.	**Safe**
0.51 - 1.00	1,137 - 2,272	**Moderate risk:** Do not feed to pregnant animals. Limit to less than 50 percent total intake for all other animals.	**Slight risk**
1.01 - 1.50	2,273 - 3,409	**High risk:** Exercise extreme caution when feeding. Limit to 33 percent of the ration.	**Moderate risk**
1.51 - 2.00	3,410 - 4,544	**Severe risk:** Do not feed to any animals free choice. If using in a mixed ration, limit to 25 percent of the ration.	**High risk**
2.01 - 2.50	4,545 - 5,679	**Extreme risk:** Do not feed at all.	**Severe risk**
2.51 and up	5,680 and up	**Extreme risk:** Do not feed at all.	**Extreme risk**

[1]The North Carolina Department of Agriculture and Consumer Services Forage Testing Lab reports nitrate levels as percent nitrate ion.

[2]Use the same feeding precautions given for the risk category for unadapted animals.

Because the forage came from several different cuttings, bales were sampled individually, and there was a great deal of variation from bale to bale. About half the bales had almost 3 percent nitrate (which is typical of levels found where death loss is high), and these bales had to be destroyed. The other bales ranged from .25 to 1.39 percent, and were successfully fed to the cows. In this situation, individual bale sampling was required to safely feed the hay.

Feed high-nitrate hay to animals in low-risk groups

Producers who have hay with a range of nitrate levels should follow the feeding guidelines in Table 2. Generally within those guidelines, hay with the highest levels of nitrate should be fed to animals in the lowest-risk category, which would include open cows (following calving but before the breeding season) or growing calves (stockers or developing replacement heifers before breeding). This means producers should refrain from feeding the higher-nitrate hay until the end of the calving season and then should finish feeding it before the breeding season begins. This is only possible on farms with a tightly controlled breeding season.

Blending forages

Blending high-nitrate forages with low-nitrate feeds is a strategy to use whenever possible. This is especially helpful when using total mixed rations where intake of a given animal can be controlled. Blending may not be of much help when feeding hay free-choice, because if offered one high-nitrate bale and one low-nitrate bale, a cow may consume only the high-nitrate forage. To blend round bales, roll out some low-nitrate hay and later roll out some high-nitrate hay so that all animals get some of each.

Use animal adaptation

Animal adaptation is a key management strategy for using high-nitrate forages. Losses from nitrate toxicity are much greater in animals not adapted to nitrate. Research has shown that growing, non-pregnant cattle can handle high levels of nitrate if the level in their diet is increased gradually over several months. The bacteria in the rumen that degrade nitrate to ammonia for bacterial protein synthesis multiply when nitrate is available to them. If a producer analyzes forages for nitrate, gradual adaptation can help minimize risk. Adapted animals can safely be fed higher levels as shown in Table 2. To adapt the cattle, start by feeding the lowest-nitrate hay and then work up to higher levels. Even with adaptation, feeding hay free-choice is risky when the hay has higher than 1.5 percent nitrate ion.

High-nitrate pastures

Potential for nitrate toxicity is lower in grazed forage than in hay with the same level of nitrate due to several factors. Animals at pasture eat more gradually than those on hay, and the nitrate is released more slowly from fresh than from dried forage. Grazing animals also tend to be naturally adapted to nitrate because levels change gradually over the grazing period. Also, when cattle are grazing they tend to be selective and don't graze the entire pasture close to the ground (where nitrate is highest). Hay cutting, by contrast, removes the forage in a uniform manner, including the lower stem base where nitrate is highest.

Stubble is high in nitrate

As indicated above, nitrate levels vary with location in the plant. Nitrate tends to accumulate in the lower stem, so cutting hay very short or allowing cattle to overgraze and eat the lower stem bases can cause them to take in more nitrate. This is often a problem in millet or sorghum x sudangrass hybrids. Growers are cautioned to leave at least 6 inches of stubble with these forages, but cattle will eat them to the ground if they are hungry.

In research done in Sampson County, North Carolina with bermudagrass irrigated with swine lagoon effluent, it was observed that under hay-cutting conditions, the lower 3 inches of the forage contained 1.3 percent nitrate ion, while the portion above 3 inches contained only 0.7 percent nitrate ion.

Nitrate in drinking water

If it is known that cattle will be drinking high-nitrate water, this should be a consideration as well as in monitoring forage nitrate levels. Water must have quite high nitrate levels for it to significantly increase total nitrate intake. Nitrate in water is expressed as ppm nitrate-nitrogen. Assuming water intake is typical, water nitrate can be compared to a forage nitrate equivalent by dividing by 500. For example 100 ppm nitrate-nitrogen is approximately equal to .2 percent nitrate ion in forage. Nitrate in water, however, tends to be more toxic than nitrate in forage because it is immediately available in the rumen. Because of this, producers should avoid water higher than 100 ppm nitrate-nitrogen.

Bacterial inoculation can aid in animal adaptation

One recent management option for producers is a commercially available oral paste containing the bacterium *propionibacterium P5*. This bacterium can degrade nitrate to ammonia without the accumulation of nitrite and has the unusual ability to develop a large and stable population in the rumen. Research has shown that using this material at least 10 days before nitrate exposure may help prevent acute toxicity. Field experiences with this product have generally been good, but this option should be used to provide an extra measure of protection and not in place of the many other management practices discussed in this publication.

Sheep, goats, and horses

Much less is known about nitrate management in ruminants other than cattle. However, the management considerations and toxicity thresholds discussed in this publication can be applied to sheep and goats. Horses are also at risk from nitrate poisoning, but very little research is available. To be safe, horse owners are advised to not purchase hay with more than 1 percent nitrate ion and to limit dietary levels to 0.5 percent after dilution with other feeds (see *Managing Pastures to Feed Your Horse,* AG-524).

Summary

Producers must understand how plants develop high levels of nitrate and how to manage high-nitrate forage if they find they have some on hand. This is especially important for producers using nitrate-accumulating forage species and for those who apply high levels of nitrogen fertilizer on forage crops. Routinely testing forages, adjusting nitrogen application rates and timing, and applying animal management techniques will limit the potentially fatal and costly risks associated with unknowingly feeding high-nitrate forage.

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