CLEMSON EXTENSION

Forage Leaflet 13 July 2008 FORAGES

Defining and Managing Nitrates in Forages

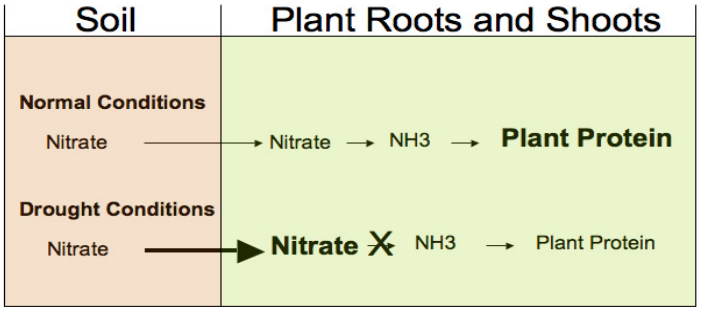
Most producers are familiar with high nitrate levels in forages; however, each year livestock are often killed by toxic levels of this compound. Ruminants like cattle, sheep and goats are particularly sensitive to high nitrate levels. Awareness of factors that cause forages to accumulate nitrate levels can help producers to avoid this problem. In this bulletin, causes of nitrate accumulation and toxicity will be reviewed. Potential plant and animal management strategies to prevent these problems will also be discussed.

WHAT CAUSES NITRATES TO ACCUMULATE IN PLANTS?

Under good growing conditions, plants absorb nitrates from the soil and convert them into plant proteins. When plants have enough moisture and light, nitrates are used to build plant tissues and rarely accumulate to harmful levels.

Nitrates normally accumulate in plants when certain forage species are exposed to stresses that decrease plant growth. The most common cause of nitrate accumulation is drought stress. Nitrates are normally taken up through roots, reduced, and deposited in plant proteins (Figure 1). During drought conditions, plants absorb nitrate from the soil, but are unable to reduce this nitrate and convert it into useful proteins for plant growth. As a result, plant nitrates increase to toxic levels. Small grains (wheat, cereal rye, and most frequently oats) and annual ryegrass in fall or spring can also accumulate high nitrate levels. Heavily fertilized pastures of small grains and ryegrass are most frequently observed to accumulate nitrates after several days of cloudy, overcast weather. Other stresses like spraying with 2,4-D can also increase nitrate accumulation in some plants; however, this happens on an infrequent basis.

Figure 1. Nitrate routes in plants.



Nitrogen fertilizer application may also increase nitrate content of plants. High nitrogen rates can overwhelm a plant's ability to convert nitrate to protein and cause nitrate concentrations to rise. In normal growing conditions, plant nitrate levels should only be slightly elevated for one to two weeks after fertilization. However, when plants are stressed or extremely high nitrogen rates are applied, dangerous nitrate amounts can be present until plants "grow out" of the nitrate buildup. Two or three weeks of active growth are often all that is needed for plant nitrate levels to reach acceptable levels.

Plant species also affects the potential for nitrate poisoning. Several plant species are notorious for accumulating nitrates. Corn, sorghum, sudangrass and sorghum-sudan hybrids are commonly reported to have high nitrate levels, and millets also accumulate nitrates. In fact, according to data from Oklahoma, millets may accumulate more nitrates than sorghum-sudan hybrids. This is certainly not a reason to avoid pearl millet because in much of the South millet has several advantages over sorghum-sudan hybrids. For example, pearl millet will produce much higher yields than sorghum-sudan in acid, sandy soils and does not cause prussic acid poisoning following the first killing frost.

Several common weeds, particularly those in the sorghum family like johnsongrass, can also accumulate nitrates. Cattle will often select

johnsongrass over bermudagrass under grazing conditions or consume large amounts of johnsongrass in contaminated hay so be careful with these weeds and forages if they are harvested under dry or other stressful conditions. Other weeds noted to accumulate nitrates are pigweed and lambsquarter.

WHY ARE ANIMALS SUSCEPTIBLE TO NITRATES?

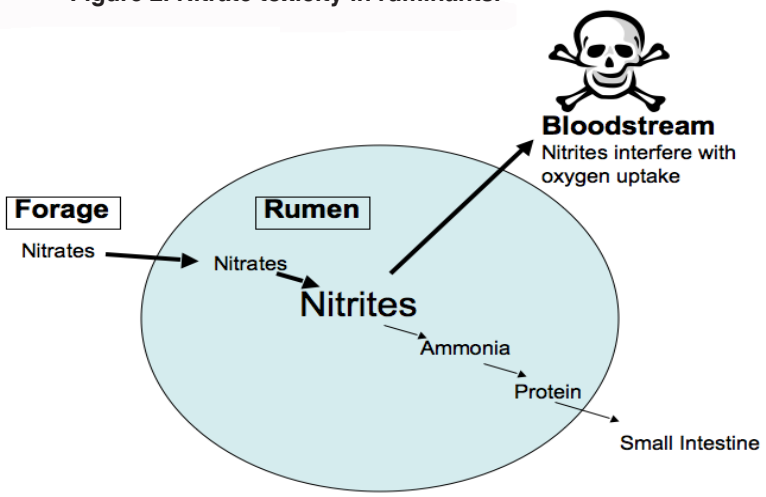
High nitrates (NO_3) in plants are not the true cause of animal toxicity. Nitrites (NO_2) cause the actual animal symptoms. This seemingly unimportant fact actually translates to important management tools that can be used to prevent nitrate poisoning. To comprehend these management tools, processes in the digestive tract must first be understood.

When animals consume normal levels of nitrate-N (i.e. less than 500 ppm NO3-N) in forages, typically no problems are observed. In the rumen, nitrate is normally converted to nitrite which is then converted to ammonia and protein for animal use (Figure 2). However, when high levels of nitrate are consumed the system is altered. Nitrate is rapidly converted to nitrite in the rumen, but ammonia conversion is typically slow. This allows nitrites to accumulate and pass into the bloodstream. Note that the conversion takes place in the rumen, which is why cattle, sheep and goats are most commonly affected by nitrate poisoning. Since horses are nonruminants, extremely high nitrate levels are necessary before any nitrate toxicity symptoms appear. Once in the bloodstream, nitrites react with hemoglobin and prevent oxygen from attaching to blood cells. This literally causes animals to suffocate because oxygen cannot be transferred from an animal's lungs to its bloodstream. This is why animals that die from nitrate poisoning have labored breathing immediately before death, chocolate-brown colored blood, and purple tissue around the eyes and mouth.

MANAGEMENT TOOLS TO AVOID NITRATE TOXICITY

Now that the mechanism of nitrate poisoning is understood, logical management options can be discussed. The easiest method to prevent nitrate toxicity is to prevent plants from accumulating

Figure 2. Nitrate toxicity in ruminants.



nitrates. This, of course, is usually impossible. In some cases irrigation can be used to prevent drought stress and nitrogen can be "spoon-fed" in split applications to reduce nitrate accumulation. If dry weather has severely limited plant growth and it is possible to delay hay harvest or grazing, try to do so. This is particularly important where nitrogen fertilizer has been applied at high rates prior to dry weather. It is normally safe to graze or cut hay about 10-14 days following an adequate rain. An adequate rain is one that supplies enough water for good, sustained plant growth. This grow out period allows time for nitrates to be converted to proteins in the plant.

Nitrate concentrations are normally greatest in the lower stem portions of plants. Leaves and seedheads generally contain low levels of nitrates. Grazing plants a little lighter than normal can decrease nitrate intake, improve diet quality and increase plant regrowth rates. Cattle grazing lightly stocked pastures will generally select leaves and avoid stems. This does not mean that lightly stocked summer annual pastures will not cause nitrate toxicity. For example, cattle turned into a drought stressed bermudagrass hayfield may selectively grass weedy species like johnsongrass which may contain the highest levels of nitrates. In fact, selective grazing is one reason that turning out a "sacrifice animal" to "test" for high nitrate levels is an extremely risky practice. It is just as likely that the tester animal will consume low nitrate forages as those that have accumulated toxic levels of nitrate. This puts the entire herd at risk when the pasture is fully stocked.

Table 1. Nitrate-N values of forages and feeding precautions.

Content of Nitrate Nitrogen (dry matter basis)	Comment
0 - 1000 ppm	This level is considered **safe to feed under all conditions**.
1000 - 1500 ppm	This level should be **safe to feed to nonpregnant animals under all conditions**. It may be best to limit its use to pregnant animals to 50 percent of the total ration on a dry basis.
1500 - 2000 ppm	Feeds are fed safely if **limited to 50 percent of ration's total dry matter.**
2000 - 3500 ppm	Feeds should be **limited to 35 to 40 percent of total dry matter in the ration.** Feeds containing over 2000 ppm nitrate nitrogen **should not be used for pregnant animals.**
3500 - 4000 ppm	Feeds should be **limited to 25 percent of total dry matter in ration. Do not use for pregnant animals.**
> 4000 ppm	Feeds containing over 4000 ppm nitrate nitrogen are potentially toxic. **DO NOT FEED.**

NOTE: Clemson University uses Nitrate-N testing. Other public and private testing laboratory values may need to be adjusted to this basis for accurate determination of feedstuff nitrate concentrations. To adjust ppm nitrate to ppm nitrate-N multiply ppm nitrate by 0.23.

Once nitrates have accumulated in plants these levels can only be reduced by being converted into proteins. This can occur by plants growing out of high nitrate concentrations or through bacterial conversion in the rumen or silage pit. Generally, beef cattle can process concentrations of 1000 ppm nitrate-N in hay. Higher levels should be fed with caution and mixed with other feedstuffs to dilute nitrates (Table 1). Animals can adapt to higher nitrate concentrations over long periods of time, but extent and speed of adaptation is impossible to predict and is dependent upon the condition and production stage of the animal.

Blindly depending upon animal adaptation to higher nitrate levels is risky at best and completely reckless at worst.
There is no substitute for forage testing to determine if dangerous levels of nitrates are present. Nitrate levels can vary within a field, so be sure to sample an adequate number of bales or plants for accurate testing. Hay probes should be used whenever possible to obtain cores from multiple bales. If one area of a field appears particularly drought stressed (i.e. sandy areas), store and sample hay from that area separately until nitrate levels are determined. Many county agents have hay probes and can assist you in submitting samples to the Clemson University Agricultural Service Lab for nitrate-N analysis.

FEEDING HIGH NITRATE FORAGES

When a feedstuff has been determined to have a potentially toxic level of nitrates, the forage may be fed if appropriate cautions are taken. The following options exist:

1) *Consider the class and condition of animals to receive the forage*. Animals such as lactating

cows and stockers, from whom a high level of performance is expected, may show reduced performance at lower levels than indicated in the chart for animal death. Animals in poor condition will also be affected at lower levels of nitrate than animals in good to excellent condition. For example, animals with heavy parasite loads and subclinical anemia levels already have a lower capacity for transporting oxygen in the blood. Low levels of nitrate in forages will compound this condition and can result in death.

2) *Do not allow hungry animals access to high nitrate pastures or hay bales*. These animals can gorge themselves resulting in a large "pulse dose" of nitrates.
3) *Dilute the forage with low-nitrate forages*. This can be done by feeding less high nitrate silage or hay or by limiting the time animals are allowed to graze. If dilution is practiced, refer to Option #2 above. Fill animals with low-nitrate feedstuffs first to prevent gorging.
4) *Feed an energy supplement*. Supplementing energy concentrates increase the rate that nitrites are converted into proteins in cattle and help offset high nitrate levels. Supplements containing urea or ammonia should be avoided as these will actually compound the problem. Ensiling can reduce nitrates in forage by up to 60% due to bacterial conversion. This data is from forage crops ensiled in bunker silos; however, it is logical to assume that well fermented round bale silage should perform similarly. Unfortunately, nitrates do not decrease in stored dry hay.

Conclusion

Nitrate problems can be avoided if producers are aware of factors that cause buildup and how animals process nitrites. Be particularly cautious when planning to graze drought stressed corn, millets, sudangrass and sorghum x sudan hybrids. Any fields (or hay) suspected of having high nitrate levels should be tested prior to feeding and appropriate feeding precaution taken to avoid animal death.

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