MANAGEMENT OF NITRATE AND PRUSSIC ACID IN FORAGE CROPS

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ABSTRACT

The two factors of drought conditions and export markets are focusing recent attention on nitrates and prussic acid in forages. During normal years, nitrate-nitrogen (NO_3-N) taken up by crops is quickly converted into protein. When forages grow under drought stress, however, they tend to accumulate nitrate. Alternative forages such as sorghums and sudans tend to accumulate even higher levels, with the added problem of potentially toxic prussic acid levels. Nitrate-nitrogen in excess of 1400 ppm is considered to be potentially toxic to ruminants. Surveying samples submitted to Servi-Tech Laboratories this past summer shows a range of <100 ppm to >19,000 ppm NO_3-N, with an average of 2200 ppm. Accurate determination of nitrate levels is critical to management of high-nitrate forages. Prussic acid poisoning can occur when animals are fed sorghum or its close relatives. Stress such as drought or frost leads these plants to produce higher levels of dhurrin, a compound containing hydrogen cyanide (HCN). Cyanide is toxic when levels exceed 300-500 ppm HCN on a dry basis. Factors contributing to high nitrate and prussic acid levels are discussed. Recommendations are presented to provide management guidelines to utilizers of these forages.

Key Words: nitrate, prussic acid, alternative forages, management, forage quality, drought stress, HCN, dhurrin

INTRODUCTION

Much of the western U.S. was haunted by drought again this year, focusing much attention on climatic conditions. Coupled with that, the west and central high plains faced a cool spring, further limiting growth of forages. Although moisture in the last month or so has helped restore depleted soil moisture, it arrived too late to be of much help for this year's crops.

Nitrate toxicity. Plants take up nitrogen in the form of nitrate (NO_3^-), which is then converted to protein. When plant metabolism is slowed by stressors such as drought, cool temperatures, hail, or other physiological stress, then nitrate accumulates in plant tissues. This occurs due to luxury uptake of soil nitrate coupled with decreased conversion of NO_3^- to protein. This causes no harm to the plant itself, and in fact occurs to some degree in every agronomic crop even in normal years. Problems only occur when forages are consumed by livestock.

Upon ingestion by ruminants, plant NO_3^- is reduced to nitrite (NO_2^-) and eventually to ammonium (NH_4^+) by rumen microbes. The ammonium is then converted into microbial protein. When nitrate is present in excess amounts, a surplus of nitrite is produced. This nitrite is absorbed into the bloodstream and complexes with blood hemoglobin, forming methemoglobin. Red blood cells containing methemoglobin no longer carry oxygen in the

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blood, thus the animal may die from asphyxiation at the cellular level. Therefore, *nitrite* toxicity is actually the problem, but it results from excess *nitrate* in forages and is commonly referred to as nitrate toxicity.

Nitrate toxicity may manifest in hours or it may take days to appear. Nonspecific signs of nitrate toxicity include weight loss, reduced appetite, diarrhea, and runny eyes. Abortion may occur at lower nitrate levels with no other symptoms. Acute toxicity symptoms include labored breathing, muscle tremors, cyanosis, and collapse with coma and death following within two to three hours. Nitrate toxicity may be confirmed postmortem by chocolate-brown blood within the first few hours after death (blood reverts back to its normal color after that). Veterinary diagnosis and treatment of nitrate toxicity is generally recommended, with emergency infusion of methylene blue as an antidote indicated in acute nitrate toxicity.

So what are "safe" levels of nitrate-nitrogen in forages? Surveying the literature shows a wide range of "safe levels" and also shows numerous reporting units, with ppm NO_3^-, ppm KNO_3, ppm NO3-N, and %$NO3^-$ being most common. (The author has previously recommended all labs standardize on ppm NO3-N as a reporting unit to lessen the confusion associated with numerous reporting units). Examples can be found in the scientific literature of death occurring at fairly low levels of dietary nitrate. Conversely, examples can be found where animals are fed rations containing high levels of nitrate with no harm. The reason is that factors other than feed nitrate content affect toxicity. These factors include animal stress, amount of forage consumed, how quickly an animal eats, plant part(s) consumed, adaptation by animals, amount of grain fed, and water nitrate concentration. Values considered "safe" in the literature range from 1000 to 3000 ppm NO3-N. At Servi-Tech Laboratories, we recommend keeping diets under 1400 ppm NO3-N for ruminants. Horses are much less susceptible, and can tolerate somewhat higher levels. Since some anaerobic fermentation occurs in the cecum, however, nitrate toxicity is still a concern.

Forages vary widely in NO3-N concentration, even on the same farm. A survey of forage samples sent in to the Hastings, NE, location of Servi-Tech Laboratories in 2002 shows an average concentration of 2200 ppm NO3-N, and a range of <100 ppm (our reporting limit) to in excess of 19,000 ppm NO3-N. Thus, forage suspected of having high nitrate should be tested by a reputable laboratory prior to feeding.

Prussic Acid Poisoning. In addition to accumulating nitrate, alternative forages may also have toxic concentrations of prussic acid. This is especially true in sorghum, sudans, and closely related species. Prussic acid (also known as hydrocyanic acid or hydrogen cyanide, HCN) poisoning is caused by cyanide production in these plants under certain growing conditions. The cyanogenic molecule in these plants is dhurrin, which occurs in epidermal (surface) cells, and this molecule is nontoxic in healthy, intact cells. Mesophyll cells located directly beneath the epidermis, however, contain an enzyme that releases HCN from dhurrin. If leaves are damaged, the dhurrin and enzyme intermix, releasing cyanide.

Similar to nitrate, cyanide interacts with blood hemoglobin after ingestion and interferes with oxygen transport. Prussic acid is a fast-acting poison, usually killing the animal within minutes. Signs and symptons of prussic acid poisoning are nonspecific and are similar to nitrate toxicity: excess salivation, difficult breathing, staggering, and collapse with death from respiratory paralysis occurring soon after. The main difference is that animals with prussic acid poisoning have bright red blood that is slow to clot, whereas animals with nitrate toxicity have dark, chocolate-brown blood. A "bitter almond" smell is often detected in animals suffering from cyanide poisoning. Symptoms are usually observed too late for treatment, due to the fast-acting nature of cyanide. If there is no doubt about diagnosis, simultaneous injections of sodium nitrate and sodium thiosulfate may be administered for treatment. The sodium nitrate releases the cyanide molecules from cells, which are then complexed by the sodium thiosulfate and excreted. Treatment and survival is usually limited to a narrow window of a few hours after poisoning.

As with nitrate, ruminants tend to be more susceptible to prussic acid poisoning. This is because cud chewing and microbial fermentation both contribute to release of cyanide. Monogastric animals, on the other hand, tend to be much less susceptible, as the enzyme responsible for hydrolyzing dhurrin is destroyed in stomach acid. Again, the literature varies quite a bit in what are considered safe levels, but a range of 300 – 500 ppm HCN on a dry-matter basis is generally considered safe. Unlike nitrate, animals cannot adapt to higher HCN levels. Again, a representative sample of forages suspected of having potentially high levels of prussic acid should be submitted to a reputable laboratory for analysis.

FACTORS AFFECTING NITRATE AND HCN LEVELS

Management of high nitrate and/or HCN levels begins with understanding the factors affecting these levels. One factor that affects both nitrate and HCN is soil fertility. Research has shown that plants grown in soils deficient in P or K and with ample N tend to accumulate nitrate, and if in the sorghum family, tend to also accumulate HCN. Overapplication of N can lead to imbalances as well. Applying high amounts of N fertilizer or manure late in the season increases concentrations as well. Split nitrogen applications reduce the potential for toxicity, provide better nutrient distribution, and may be more economical as well.

Stress is another factor common to both nitrate and HCN toxicities. Of plant stressors, drought is usually the biggest culprit. Roots continually take up nitrate, but high daytime temperatures inhibit protein synthesis. After a drought-ending rain, up to 14 days may be required for metabolism of the accumulated nitrates. Similarly, drought-stunted plants may accumulate HCN. New growth following a drought-ending rain becomes dangerously high in HCN, and is highly palatable. Frost, hail, disease, and other stressors also influence accumulation of both nitrate and HCN. A killing frost will cause release of HCN, rendering plants safe to graze after a period of at least four days providing there is no regrowth. Such a frost has no net affect on nitrate levels, however.

Animal stress can increase susceptibility to nitrate and prussic acid toxicity. Hunger is also a contributing factor, due to the effect that forage quantity consumed and meal length have on toxicity.

Harvest method also affects HCN and nitrate levels. Here is where some of the misperceptions often arise. Animal grazing is usually the least desirable, as it is difficult to control intake and prussic acid levels are highest in fresh forage. Haying doesn't change nitrate concentrations at all, but typically renders all but the highest HCN-containing forages safe. This is because HCN is volatile and dissipates during curing. Ensiling forages high in HCN also reduces HCN substantially, and can reduce nitrate 30 - 60%.

RECOMMENDATIONS

Sampling. Sample forages harvested for hay according to current National Forage Testing Association (NFTA) guidelines, found at http://www.foragetesting.org, and submit promptly to the laboratory in a sealed plastic bag. Ideally, samples for HCN analysis should reach the lab on ice and within 6 hours of sampling. Of course, haying typically results in almost complete dissipation of HCN, and analysis of HCN in dry hays is not generally recommended.

When sampling green chop or silage, collect samples at six locations from the active feeding face of the pit or mound. Mix the sample thoroughly and reduce size by coning and quartering. Place sample in plastic bag and send to the laboratory for analysis.

Getting a representative sample from standing forage is difficult. Cattle and other grazers tend to be selective in which plants and plant parts they graze. Clipped samples taken at a "typical grazing height" for the animal species of concern typically will slightly overestimate nitrate intake and underestimate HCN intake due to their distribution in plants. However, this sample does give a general idea of the potential for problems and should be taken prior to grazing any field suspected of having toxic levels of either nitrate or prussic acid.

Harvest technique. Nitrate tends to accumulate in lower stalks, so increase harvest height to decrease nitrate concentration in the harvested forage. Consider ensiling where the forage can be utilized locally, as this will reduce nitrates by roughly half. When harvesting by grazing, manage stocking rate to avoid heavy grazing. Avoid turning out animals onto high nitrate forages or forages containing elevated HCN levels without prior feeding. Remove animals from susceptible forages for 10-14 days following a drought-ending rain. Adapt animals gradually to high nitrate feeds, and avoid feeding potentially toxic feeds to stressed livestock.

Dilution. High nitrate forages and forages with high HCN levels may be safely fed if diluted to safe levels. Dilute out high nitrate or prussic acid forages with low nitrate/HCN forage, byproducts, or supplemental grain in a balanced ration. Grain supplementation can be highly effective in managing higher nitrate feeds as the carbohydrates benefit rumen microbes and enhance reduction of nitrite to ammonium.

Stress. Minimize animal and plant stress as much as possible. Provide adequate quantities of clean, low nitrate drinking water.

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