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Nitrate Accumulation in Forages

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Nitrate poisoning in cattle has been recognized for many years. Some cultivated forages in addition to several common broadleaved and grassy "weeds" can accumulate nitrates. The toxic compound is actually nitrite which occurs during the metabolism of nitrate. Livestock are always consuming some level of nitrate from drinking water and forages. Nitrate consumption becomes a problem when the quantity consumed overrides the capacity of the ruminal microbes to completely convert the nitrates into ammonia and microbial protein.

Factors affecting nitrate levels in fresh and harvested forages

Plant factors Forage sorghum, grain sorghum, sudangrass, sorghum*sudangrass, pearl millet, and small grains forages are common forage crops that can accumulate nitrates at high levels. Johnsongrass, pigweed, Russian thistle, sunflowers and kochia are some common weedy species that accumulate nitrates and may be present in and around pastures and fields.

Nitrates are usually higher in young growth. But, stress can lead to nitrate accumulation at any stage of growth. The highest concentrations of nitrates occur in the bottom one-third of the stalk of the plant. Concentrations of nitrates are low in the leaves of the plants while the seeds of the plant contain very little, if any, nitrate.

Weather and climate factors during the growing season Live plants will continually absorb nitrate from the soil except under extreme drought conditions. Nitrates accumulate in the plant during periods of stress or slowed growth because conversion of nitrate to other N-containing compounds, such as amino acids, is slowed. Dry soil conditions, cloudy overcast days, cool ambient temperatures, disease or insect damage, frost or physical damage, individually or in combination with one another, can lead to nitrate accumulation. Dry, hot weather will increase plant nitrate levels but levels will increase further when the extended dry period is followed by rain and/or wet overcast weather. Following a period of nitrate accumulation, several days of good growing conditions are necessary before plant nitrates are metabolized to lower levels.

Management factors Nitrogen fertilization increases the quantity of nitrogen available to the plant and can increase nitrate levels. Poor availability of other soil nutrients such as sulfur, phosphorus and potassium can retard nutrient metabolism and plant growth and impede nitrate utilization by the plant.

Unlike prussic acid, another potentially toxic compound in some forages, nitrate concentrations will not decrease when forages are harvested for hay. However, ensiling fresh, green forages will decrease the nitrate concentrations in the ensiled feed.

Even though standing forage may contain high nitrate levels, the nitrate concentration in the harvested forage can be reduced by raising the cutting height during harvest. Recall that most

of the nitrate accumulates in the bottom of the stalk. So, a great deal of nitrate can be left in the field if the plant is cut 10-12 inches above the ground.

Nitrate concentrations

The risk of nitrate poisoning is usually evaluated from the nitrate concentration in the forage. Concentrations are expressed in various ways depending upon analytical procedure and the laboratory reporting the results. When interpreting lab reports, be certain what units are reported by the lab. Table 1 shows some useful conversion factors.

Table1. Conversion factors for expressing nitrate concentrations.

Potassium nitrate (KNO_3), ppm X .061	= Nitrate (ppm)
Nitrate-nitrogen (NO_3-N), ppm X 4.42	= Nitrate (ppm)
% Nitrate (NO_3) X I0,000	= Nitrate (ppm)

Although concentration is indicative of the potential for nitrate poisoning, total nitrate intake is the determining factor. A low nitrate forage consumed in large quantities can be toxic while a high nitrate forage consumed in limited amounts can be safe. Table 2 lists some general guidelines for concentrations and intakes that can lead to poisoning.

Table 2. Concentration (dry matter basis) and intake of nitrate (NO_3) and potential effects on livestock.

Nitrate (ppm)	Nitrate (%)	Nitrate Intake (mg/lb BW)	Comment
0 – 1,500	0 - 0.15	0-20	Safe for pregnant cattle
1500 – 5000	0.15 -0 .50	20-60	Potential for early term abortions & reduced rebreeding performance
0 – 5000	0 - 0.50	0-60	Safe for nonpregnant cattle
5000 – 10,000	0.50 - 1.0	60-120	Potential for mid-to late term abortions, decreased growth, and reduced milk production
10,000 +	1.0 +	120 +	Acute toxicity symptoms and death; Abortions

Managing Nitrate-Containing Forages for Cattle

Evaluating nitrate concentrations Any standing or harvested forages with questionable nitrate concentration should be analyzed by a testing laboratory. Field kits using diphenylamine are indicators of nitrate presence or absence but are not quantitative tests and are not always accurate.

Hot spots are present in all fields. These spots, to name some, are shallow soils where plants stress more, areas that catch more runoff and may catch more N fertilizer with the runoff, and spots with a greater presence of nitrate-accumulating weeds. So forage samples should represent the entire field. Several plants should be collected from various locations in the field. Samples of standing forage should be collected by cutting the whole plant at the same height

the plant would be cut during harvest. Samples of forage that has been cut for hay, but not baled, can be collected from the windrows across the entire field. Again be certain that the entire field is sampled and that the samples are representative of the leaf and stem mixture in the forage.

Hay bales are best sampled using a core sampler. When sampling baled hay, samples should be taken from several bales to characterize the nitrate levels in the entire stack.

It is always best to sample and analyze before harvesting the forage. Once the forage is harvested, management alternatives become limited. Once the forage is harvested, the nitrate levels do not decline unless the forage is ensiled.

Alternatives pre-harvest and at harvest if nitrate concentrations are high

- If concentrations are high in standing forage, one alternative is to delay harvest of the forage. If conditions allow the plants to grow, the potential toxicity in the forage may decline as the plants metabolize existing nitrate. A more mature harvested forage of lower nutritional value may be worth more than a forage harvested with a high nitrate concentration.
- Raising the cutting height at harvest can reduce nitrates in the harvested forage. The lower section of the stalk contains the higher nitrate concentrations. So by raising cutting height, more of the concentrated nitrate is left in the field rather than captured in the hay.
- Ensiling rather haying can reduce nitrate concentration of the harvested forage. Bacterial metabolism will convert the nitrate during the ensiling process. On average, nitrate concentrations will be reduced 40-60% if the forage ensiles properly.

Management to reduce the incidence of toxicity at feeding or grazing

The ability to safely utilize forages that contain enough nitrates to potentially cause problems depends on the concentration of nitrate in the forage and the ability of the producer to manage the grazing or feedout of the forage.

- In some cases, the nitrate concentration may be too high to manage. In this case the forage will have to be plowed down, spread across the field for fertilizer, or destroyed.
- Diluting high nitrate forages with low nitrate feed and forages is probably the most effective method for utilizing forages with very high nitrate concentrations. This is best accomplished by physically mixing the forage with other feed sources. Mixing reduces the opportunity to preferentially consume one source versus the other. If a producer can physically limit the daily consumption of the nitrate-containing forage, then it may be possible to separately deliver limited quantities of the forage to the cattle along with other feeds. However, free-choice access to the nitrate-containing forage with the assumption that the cattle will limit intake is not an option.
- Be certain cattle are full prior to allowing access to nitrate-containing forages. Filling the cattle prevents high levels of nitrate intake initially and also dilutes the nitrates in the rumen.
- Adapt cattle to nitrates. Ruminal microbes will adapt to higher nitrate concentrations in feeds. Feeding small quantities of nitrate-containing forages over several days promotes adaptation. When grazing nitrate-containing forages, limit grazing time for the first 6 to 8 days by gradually increasing to full time grazing. Grazing time can be limited by physically limiting grazing or by feeding other hay or feeds to the cattle.
  When feeding hay containing nitrates, slowly increase the amount fed daily, or dilute the hay with non-toxic hay and gradually increase the proportion of the nitrate-containing hay.

- Supplementing grain can reduce risk of nitrate toxicity. Grains provide additional energy to the microbes and promote the conversion of nitrates to nontoxic compounds.
-In grazing situations, release the cattle into the pasture when risk of high nitrate concentrations is lower. For instance, do not graze immediately following weather conditions that stimulate nitrate accumulation. Also, in the afternoon following a sunny morning, nitrate concentrations will be lower than early in the day.
- Stock lightly when grazing so that cattle can select the low-nitrate portions of the plants. Also, do not force cattle to consume stalks, even in the winter when the forage is dormant.
-Be certain adequate amounts of drinking water are available. Water dilutes nitrate concentrations in the rumen and reduces the potential of toxicity.
-Use a direct-fed microbial product that contains *Propionibacteria*. *Propionibacteria* utilize nitrite, the toxic intermediate compound produced from nitrate in the rumen. A commercially available product, Bovipro, is a *Propionibacteria* product that can be administered orally or top-dressed on feed.