MANAGEMENT OF FORAGES WITH HIGH NITRATES

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ABSTRACT

Livestock producers are often confronted with how to feed high nitrate forages. The concern with nitrate consumption by livestock is the rapid conversion of nitrate to nitrite in the rumen. Once converted, excessive nitrites are then absorbed into the bloodstream and bind with hemoglobin to produce methemoglobin which can result in a range of health issues in livestock, namely early-term abortions and/or reduced breeding efficiency. Producers operating in the forage industry who either produce hay for their livestock or hay for sale can help to minimize nitrate accumulation in plants by following crop production guidelines and reduce nitrate consumption by livestock by observing feeding and grazing strategies. Producers should always test forages for nitrate accumulations through a qualified lab before feeding to livestock.

INTRODUCTION

High nitrates (NO3) can accumulate to toxic levels in many forage crops. High nitrates have been recorded in both cool-season annuals (i.e., oats, rye, wheat, barley, triticale, spelt, etcc.) and warm-season annuals (i.e., sorghum, sudangrass, millet, corn) as well as perennial forage species like bromegrass, orchardgrass, fescue, sweetclover and alfalfa (Provin and Pit 2012, Glunk et al. 2015). Additionally, many of the plant species in the Goosefoot Family (Chenopodiaceae), are common annual weeds associated with cultivated in the western US, also are considered high nitrate accumulating plants. Some common members of the Goosefoot family are Kochia (*Kochia scoparia)*, Russian Thistle (*Salsola iberica)*, and Lamb's Quarter (*Chenopodium berlandieri*) (Provin and Pit 2012).

First reported in 1895, livestock poisoning from plant nitrates has since been realized as a common occurrence and concern for livestock producers. More accurately termed nitrite (NO2) poisoning, the condition and associated losses were common in the 1930s when large acreages of drought-stricken oats were harvests and fed to livestock as forage (Westcott et al., 2012). Nitrate alone is not toxic to animals and in the rumen nitrate is broken down to nitrite and then typically to ammonia (NH3); however, when forages contain excessive levels of nitrate, the rumen becomes overwhelmed and much of the nitrate is not full processed into ammonia and the intermediate step, nitrite, enters the bloodstream through the small intestine Hemoglobin carries oxygen in the bloodstream; however, when it binds with nitrite methemoglobin is formed which reduces or even stops oxygen transport to in the body. This low oxygen supply can cause many negative effects in livestock and severity of animal poisoning is often a combination of the level the and duration exposure. Chronic toxicity results from animals consuming small amounts of

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high-nitrate forages for longer time periods, while acute toxicity results from animals consuming large amounts of high-nitrate forages in a short time period (Kahn 2005).

ANIMAL SIGNS OF TOXICITY

Signs of early or chronic toxicity: watery eyes, reduced appetite, reduced milk production, rough hair (unthrifty appearance), weight loss or no weight gain, night blindness, and abortion.

Signs of acute toxicity: accelerated pulse rate, labored breathing, shortness of breath, muscle tremors, weakness, staggering gait, cyanosis (membranes such as the tongue, mouth, vulva, and the whites of eyes, turn blue), and death.

Treatments exists for both chronic and acute nitrate poisoning; however, both the risk and speed of nitrate poisoning make management of nitrate accumulation in forages the most desirable option for producers (Cash et al. 2006).

MANAGEMENT OF GROWING CONDITIONS

All plants contain detectable amounts of nitrate and under normal growing conditions, nitrate is quickly converted to protein when adequate sunlight energy is available. The accumulation of nitrate in plants occurs when uptake from the soil exceeds plant photosynthetic use for protein synthesis (Sidhu et al. 2011). Many factors contribute to accumulation of plant nitrates and producers and agricultural advisors need to be aware of these conditions when they occur during forage production.

Stressed growing conditions are one of the most significant factors contributing to nitrate accumulation in forage plants. Stressed conditions include: drought, frost, hail, excessive shading, low temperatures, herbicide damage, soil nutrient, and mineral deficiencies, and damage from pest insects and/or diseases (Gunk et al. 2015, Sidhu et al. 2011). Nitrate accumulation varies by crop and crop variety, forage management, soil fertility, plant part, and plant maturity (Table 1).

Plant species do vary in their ability to accumulate nitrates and even different varieties of cereal forage crop will exhibit differences. Selecting crops and cultivars that have lower accumulation potential can help reduce toxicity levels. Also consider the environmental growing conditions for each year, separately, and adjust inputs accordingly. Additionally, forage crops grown on soil with excessive Nitrogen fertilization are suspect for nitrate accumulation (Table 1).

Additionally, phosphorous, potassium, and sulfur soil deficiencies will often lead to excessive nitrate accumulation in plant tissue while sufficient levels will aid plants converting nitrates to proteins, resulting in lower total accumulations. A good practice is soil sampling and amending soil nutrient profiles according to laboratory results which result in proper soil and plant nutrient balances and efficient plant photosynthetic capabilities.

Good preventative forage production practices will aid in reducing plant nitrate accumulations. In general, soil test and apply all fertilizer according to lab results. Control nitrogen accumulating weeds in forage fields, use alternative cereal forages with high water uses efficiencies (winter and spring cereals) and in northern climates, cool-season cereal forages can be grown and harvested often before hail, drought, or frost conditions occur (Glunk et al. 2015).

Table 1. Nitrate accumulation varies among crops, varieties, plant maturity, with forage treatment and nitrogen fertilization management (adapted from Glunk et al. 2015).

Generality	Example NO_3 (ppm)		
Plant species and varieties vary in nitrate accumulation	Oats contained 1.5 times the nitrate as the average of oat, barley, spelt, spring wheat and triticale. Westford barley accumulate more nitrates than Haybet barley[1]		
Nitrates decrease as plants mature	Oats at:	Heading	5047
		Flowering	4726
		Soft dough	3027
Plant parts vary in nitrates	Oats with 100 lb N/acre:	Stems[2]	8000
		Leaves	4200
		Heads	1000
Nitrates increase with high N fertilization	Oat stems at boot stage with:	50lb N/acre[2]	6000
		100lb N/acre	8000
		150lb N/acre	12500
Ensiling tens to decrease nitrates once fermentation is complete	Corn with 200lb N/acre as:	Green forage[3]	2319
		Silage	1468

[1]Westcott et al. 2021; [2] Crawford et al. 1961; [3]Vough et al. 2006

HARVEST MANAGEMENT

If any of the above conditions occur during the growing season, those forages should be suspect for nitrate accumulation and precautions should be taken before feeding. Plant nitrate levels are highest in the morning and so harvest and/or grazing should be avoided during this time especially with fields suspected of high nitrate accumulations. Instead, delay harvest until the afternoon on warm sunny days to give plants the time needed to process any excessive nitrates accumulated during night time. The lower portions of the plants, (i.e., roots and stalks) accumulate the highest levels of nitrates followed by leaves and then grain (Strickland et al.), Kahn et al. 2005). Elevating the cutting bar at harvest above the lower 1/3 of plant stalk will help to reduce the harvested nitrates in baled forages.

Nitrates are often reduced in more mature cereal forages and levels can often be reduced by delaying harvest from stem elongation and flowering until the soft dough stage (Table 1). During drought conditions, often certain fields may receive a drought-ending rain. Under these conditions, producers should wait approximately one week before harvesting or grazing allowing plants sufficient time to process any accumulated nitrates (Fjell et al., 1991). General practices worthy of consideration are to both anticipate and test for nitrates before, during, and following any growing season stresses. Conditions such as frost, drought, insect damage, etc. can and often do results in nitrate accumulation and so identifying these events and testing forage will allow producers to harvest and stack hay in lots, according to nitrate levels. This will allow for producers to feed out hay knowing the nitrate levels and blend those forages will excessively high nitrate levels. Crimping forage crops during harvest will improve dry-down time and will also accelerate nitrogen volatilization often giving off nitrogen-based gas and denitrifying the hay prior to baling. When feeding, nitrate toxicity often occurs when animals are pastured or feed green chop, followed by hay.

Preserving forages as silage, haylage, or balage will often result in nitrate reductions of 10 to 60 percent (Glunk et al. 2015) due to the fermenting microbes converting forage nitrates to ammonia (Ziegler 2021), In traditional dried hay bales, nitrate levels are typically very stable and remain very close to the levels recorded at harvest.   Harvested forages should always be tested before feeding to livestock (Table 2).

GRAZING HIGH NITRATE FORAGES

When allowing livestock to harvest their own forage in stockpiled forage or crop residue fields, several guidelines will help minimize any associated risks. First, grazing animals typically eat at a slower rate than in a situation with harvested feeds (Strickland et al. Drewnoski et al. 2019). This will help to reduce the rate of nitrate accumulation in the animal and subsequent issues with toxicity. Grazing animals typically select plant leaves and heads first which contain substantially fewer nitrates than plant stems (Table 1). Animals should not be stocked at high densities or strip grazed as this will increase the intake amount and rate of higher nitrate stem material (Block 2020). In Nebraska, cattle were allowed to graze brassica forage mixes with whole-plant nitrate levels between 17,720 and 35,440 ppm without detrimental effects associated with nitrate toxicity. Cattle were lightly stocked allow and allowed to graze the fresh high moisture forage which further reduces nitrate release by the plant (Drewnoski et al. 2019).

Animals grazing high nitrate fields should be fed in the morning with low nitrate hay, before release onto high nitrate stockpiled forages. This will slow down the animal intake rate and help to minimize toxicity issues. The key to this strategy is gradual adaption of the rumen to the high nitrate forages. Keeping the animals mostly full with low nitrate forages while slowly increasing the high nitrate portion of the diet will aid in increasing the rumen bacteria capable of converting nitrate to ammonia. Adapted animals can graze higher nitrate forages with lower risk. Producers can also blend high nitrate forages with other feedstuffs to achieve lower total nitrate levels in a quantity of feed and allow animals access to unlimited, high-quality, and low nitrate water (Block 2020).

Finally, producers can consider grain supplementation while feeding higher nitrate forages. This strategy supplies needed energy to the rumen microbes to successfully convert high levels of plant nitrate into bacterial protein. Many cover crops with high levels of brassicas (i.e., turnips and radishes) are highly digestible and may, by themselves, provide sufficient energy to the rumen microbes and eliminate the need for grain supplementation (Drewnoski et al. 2019).

Table 2. Effect of nitrate concentration on livestock[1] as reported by Montana State University. These guidelines are more conservative than published by others (as reported in Glunk et al. 2015).

Reported on 100% dry matter basis[2] as:		
NO_3 - N (ppm)	**NO_3 (ppm)**	**Comment**
<350	<1,500	Generally safe for all conditions and livestock
350-1,130	1,500-5,000	Generally safe for nonpregnant livestock. Potential early-term abortions or reduced breeding performance. Limit use to bred animals to 50% of the total ration.
1,130-2,260	5,000-10,000	Limit feed to 25-50% of ration for nonpregnant livestock. **DO NOT FEED TO PREGNANT ANIMALS** - may cause abortions, weak calves and reduced milk production.
>2,260	>10,000	**DO NOT FEED.** Acute symptoms and death.

[1] Source: Hibbard et al., 1998; [2] If nitrate content of a feed is reported on an "as is" basis, convert to 100% dry matter basis to compare it to levels in this table. For example, silage at 40% moisture that contains 600 ppm NO_3-N on an "as is" basis contains 600 ppm/0.6 = 1000 ppm on 100% dry basis; thus it fits the second group in this table.

SUMMARY

Judicious use of fertilizers and awareness of factors inducing plant stress combined with good livestock management can help reduce losses from nitrate poisoning. Producers should always test forage nitrate levels with a certified lab before feeding. With a nitrate analyses, producers should also request forage nutritive estimates which are useful when balancing winter rations.

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