Spectrum Analytic, Inc.

EXCESS NITRATES IN DROUGHT STRESSED CORN

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Acute nitrate toxicity is much more rare than commonly assumed. However, when in doubt it is a relatively simple process to get a laboratory analysis to determine the facts

High nitrates (NO_3) in livestock feed can cause symptoms ranging from poor weight gain or milk production, to fetus abortion, or the death of the livestock. Nitrates accumulate in crops as a result of the crop being unable to metabolize nitrate into protein or other compounds, due to other growth limiting factors. Severe drought is one of the most common cause of high nitrates in forages.

Before discussing the various aspects of managing high nitrates, we should explain some of the terms and units of measure that are used. Laboratory results and other information sources may use various methods of referring to nitrates, nitrate-nitrogen, and units of measure. These terms and units of measure can easily be converted from one to another by the following formulas.

However, in order to give the reader a quick approximation of the general consensus, we have produced the following table. See later pages for information from individual Universities and suggested management options.

There is a little difference between authorities in how they report and interpret nitrate levels in corn. Some of them are reported in later pages.

	“TYPICAL” INTERPRETATIONS		
	Form of Nitrate Reported		
	Nitrate-N ($N0_3$-N)	**Nitrate ($N0_3$)**	
	Limits listed below are the upper limit in the range		**Recommendations for Feeding**
Percent	0.10%	0.44%	**Safe**
ppm	1,000	4,429	
Percent	0.25%	1.11%	Feed will generally be safe when **introduced into the ration gradually.** Use precautions listed under "Utilizing Drought Stressed Corn".
ppm	2,500	11,073	
Percent	0.30%	1.33%	**Caution:** Limit to 50% of the total ration on dry matter basis. Use precautions listed under "Utilizing Drought Stressed Corn".
ppm	3,000	13,287	
Percent	0.45%	1.99%	**Caution:** Limit to 25% of the total ration on dry matter basis. Use precautions listed under "Utilizing Drought Stressed Corn".
ppm	4,500	19,931	
Percent	>0.45%	>1.99%	**DANGER, DO NOT FEED:** High potential for toxicity.
ppm	>4,500 ppm	>19,931ppm	

Please read the entire text of this paper to gain a full understanding of the best ways to handle high-nitrate corn. It is not simply a matter of how much nitrate is in the forage.

The following is an excellent discussion of the topic taken from the publication Nitrate Toxicity, N.R. Hartwig (DMV) and S.K. Barnhart (Ext. Agron., forages); Iowa State Univ. Italics are inserted by Spectrum Analytic.

“Nitrogenous products accumulate in plants when soil nitrogen levels are high and readily available but the plant is unable to utilize it. In the rumen of cattle and sheep, nitrates (NO_3) are reduced to highly toxic nitrites (NO_2) which in turn are reduced to ammonia and then incorporated into bacterial protein (which the livestock then digest). When nitrate consumption is excessive, the reduction of nitrite to ammonia becomes overloaded, and toxic levels of nitrites accumulate in the rumen. Excessive levels of nitrites oxidize iron in the hemoglobin molecule from the ferrous to the ferric form. This compound is called methemoglobin and lacks the capacity to carry oxygen to the tissues. The result is a lack of oxygen throughout the body. High levels of methemoglobin give blood a chocolate color.

Nitrate levels can go up and down rapidly in plants. It accumulates only in the vegetative parts of plants, not in the grain or fruit. Highest levels are found in the lowest part of the stalk. Cool season grasses such as fescue, orchard grass, and timothy are not incriminated in nitrate poisoning, and legumes are seldom a problem. Green chop made from drought stressed crops such as corn grown on highly fertile soils is the most dangerous.

Silage loses more than half, in many cases 80-90%, of the nitrate in the ensiling process (some data suggests between 30 and 50%). Toxic gasses such as nitrogen dioxide (NO_2) and nitrogen tetroxide (N_2O_4) are produced in the ensiling process and may form a brown colored gas on top of the silo. Livestock and people have been killed when this gas, which is heavier than air, floats down a silo chute and into a barn or confined area. Crops that are put in a silo in an extremely dry condition may lose only 20% of the nitrate. Addition of 10 to 20 lbs. of limestone per ton of silage delays the drop in silage pH and increases the amount of nitrate removed during the ensiling process.

Nitrate may be converted to the much more toxic nitrite by bacterial action in wet bales of hay. Excessive soaking with water may result in higher levels of nitrite near the bottom of large bales and stacks.

Nitrate accumulation is usually not excessive unless adequate soil moisture is present. Drought stressed crops that receive rain a few days before harvest can accumulate significant levels of nitrate. Acid soils, low molybdenum, sulfur deficiency, phosphorus deficiency, low environmental temperature (55º), and good soil aeration are conducive to nitrate accumulation. Herbicide damage to plants can also lead to significant nitrate uptake. The following plants are known to accumulate nitrate, possibly other annual grasses will as well (incorporated into table listed on the last page).

Symptoms of acute nitrate poisoning in animals are related to the lack of oxygen in the tissues. These include muscular weakness, in coordination, accelerated heart rate, difficult or rapid breathing, cyanosis, coma, and death. Less severely affected animals may be listless and only show rapid respiration when exercised. Drop in milk production, abortion due to lack of oxygen getting to the fetus, poor performance and feed conversion are seen in chronic cases. Of the crop plants, drought stressed green chop corn is the most likely to cause nitrate toxicity in Iowa. Sorghum/Sudan harvested or grazed under the same conditions may cause problems. Oat hay harvested from land that has had heavy applications of nitrate fertilizer and a rapid regrowth from rain just prior to harvest has caused a few cases of nitrate poisoning. Several weeds can accumulate nitrates but seldom cause toxicity because livestock will usually not eat them.

A useful rule of thumb is that cattle and sheep can tolerate up to 0.5% nitrate (NO_3, equivalent to 5,000 ppm NO_3, 0.11% NO_3-N, or 1,129 ppm NO_3-N) on a dry matter basis. Total nitrate intake, including from drinking water, must be considered. Feeding non-protein nitrogen such as urea does not affect susceptibility to nitrate toxicity. Intake of large amounts of nitrate at one feeding more likely to produce toxicity than intake of the same levels spread out over several hours. Livestock can adapt to higher levels of nitrate intake over a period of several days. Inclusion of grain in the diet speeds up the conversion of ammonia to protein and makes ruminants less susceptible to nitrate toxicity.

Acute nitrate toxicity is much less common then many realize. Only a few episodes have occurred in Iowa. Those feeding green chopped drought-stressed corn on highly fertile land may want to consider testing."

Toxicity Potential of Green-Chopped Corn	
Condition of Corn	**Toxicity Potential**
Corn barren, stunted, N supply normal to high	High
Barren to poor grain yield, N supply normal to high	Medium
Poor to moderate grain yield, normal N supply	Low
Corn with moderate to high grain yield	Low
Iowa State Univ.	

Many publications state that the NO_3-N level in feed must be over 0.45% (4,500 ppm NO_3-N or 2% NO_3) to cause a problem. However, some research has shown that sub-lethal levels of NO_3-N in feed can cause various problems. Garner (1958) reported that concentrations of 0.14% NO_3-N (1,400 ppm NO_3-N or 0.62% NO_3) in the ration caused reduced milk production, and levels up to 0.21% NO_3-N (2,100 ppm NO_3-N or 0.93% NO_3) caused severe problems. Higher doses were often fatal. These "critical" levels are much lower than those reported by later workers.

Wright & Davidson (1964) and Cummins (1967) reported that classical symptoms of nitrate poisoning seldom occur until the diets contain in excess of 0.35% to 0.45% NO_3-N (3,500 to 4,500 ppm NO_3-N or 1.55 to 2.0% NO_3). Other work has supported these results. Several researchers have reported that ruminant livestock can adapt to higher nitrate levels in feed if it is introduced slowly.

Interpreting a Nitrate Test

There is some disagreement among authorities as to how to interpret a feed-nitrate test. However, some customers have requested an interpretation table that incorporates the more widely accepted ranges and cautionary statements. The following interpretation is our effort to address those requests. However, you need to read the rest of this paper to understand the specific steps to be taken with high nitrate corn, as well as to appreciate the different interpretations between some Universities. The following definitions and conversions can be used to compare the different reporting units used by various laboratories.

Nitrate = NO_3, This is the entire nitrate molecule, which contains 1 atom of N and 3 of oxygen.		
Nitrate Nitrogen = NO_3-N, This is only the N that is in the nitrate molecule		
Potassium Nitrate = KNO_3, This is the common form of nitrate in the plant and is reported by some labs		
$NO_3 \times 0.226 = NO_3$-N	$NO_3 \times 1.486 = KNO_3$	$KNO_3 \times 0.139 = NO_3$-N
NO_3-N $\times 4.429 = NO_3$	NO_3-N $\times 7.214 = KNO_3$	$KNO_3 \times 0.673 = NO_3$
1.0% (of anything) = 10,000 ppm		

Iowa State University			
Form of Nitrate Reported			**Recommendations for Feeding**
$KN0_3$	**$N0_3$-N**	**$N0_3$**	
0-1.0% 0-10,000ppm	0-0.15% 0-1,500ppm	0-0.65% 0-6,500ppm	Generally considered safe for livestock
1.0-3.0% 10,000-30,000 ppm	0.15-0.45% 1,500-4,500 ppm	0.65-2.0% 6,500-20,000 ppm	Caution: Problems have occurred at this level. Mix, dilute, limit-feed forages at this level.
>3.0% >30,000 ppm	>0.45% >4,500 ppm	>2.0% >20,000 ppm	DANGER, DO NOT FEED: Potential for toxicity high

Minnesota (About the same levels as Iowa but 4 categories)	
ppm $N0_3$-N in dry matter	**Comment**
0 – 1,500	Safe level under all conditions
1,500-3,000	Feeds will generally be safe when introduced into the ration gradually. At upper end (2500-3000), limit nitrate feed to 50% of the total ration DM
3,000 – 4,500	Feeds in this range should be restricted to 25% of the total ration DM.
Over 4,500	Forages over 4500 are potentially toxic and should not be fed

Kansas (Kansas is more conservative than Iowa on the upper end)	
ppm NO_3	**"Effect on Animals"**
0 – 3,000	Virtually Safe
3,000-6,000	Moderately safe for most situations, limit use for stressed animals to 50% of the total ration.
6,000-9,000	Potentially toxic to cattle depending on the situation; should not be the only source of feed.
9,000 and above	Dangerous to cattle and often will cause death.

Nebraska (Nebraska, like Kansas, is more conservative at the upper end)		
Potentially Lethal Levels	**%**	**ppm**
NO_3 – N	>0.21%	2,100
NO_3	>0.9%	9,000
KNO_3	>1.5%	15,000

Wisconsin and Kentucky			
NO_3-N ppm	**NO_3-N %**	**NO_3 %**	**Comment**
<1,000	0.1%	0.44%	Safe. A 1,000 lb cow consuming 20 pounds of dry matter would consume about 9 g of NO_3-N or less than 1 g per 100 lb of body weight.
1,000-2,000	0.1 - 0.2%	0.44 - 0.88%	Generally safe when fed balanced rations. Best to limit to half of the total dry ration for pregnant animals and also be sure water is low in nitrate.
2,000-4,000	0.2 - 0.4%	0.88 - 1.5%	Limit amount to less than half of total ration (KY to ¼). Be sure ration is well fortified with energy, minerals, and vitamin A.
Over 4,000	>0.4%	>1.5%	Potentially toxic – do not feed.

Ohio State University			
NO_3-N ppm	**NO_3-N %**	**NO_3 %**	**Comment**
<1,000	<0.10%	<0.44	Safe
1,000-2,000	0.10 - 0.20%	0.44 - 0.88%	Generally safe when fed balanced rations. Best to limit to half of the total dry ration for pregnant animals and also be sure water is low in nitrate.
2,000-3,400	0.20 - 0.34%	0.88 - 1.5%	Limit amount to less than half of total ration. Be sure that water is safe. Be sure ration is well fortified with energy, minerals, and vitamin A.
>3,400	>0.34%	>1.5%	Potentially toxic – do not feed.

University of Florida			
NO_3-N ppm	**NO_3-N %**	**NO_3 %**	**Comment**
3,000	0.3%	1.33%	Gradually introduce feed
3,000-5,000	0.3 - 0.5%	1.33 - 2.21%	Limit silage to 50% of total ration dry matter
5,000+	0.5+%	2.21+%	Limit silage to 25% of total ration dry matter

UTILIZING DROUGHT STRESSED CORN

In all cases where high nitrate forage is to be used, the first step should be to **contact an authority in animal nutrition and forage handling.** This would be particularly important in adjusting feed rations for specific purposes, or for veterinary advice. The following guidelines are generally accepted as good practices when utilizing known, or suspected high nitrate corn for feed.

1. Raise the cutter bar to leave 12 to 18 inches of lower stalk in the field. Nitrates tend to accumulate in the lower portion of the stalks of drought stressed corn, as illustrated in the following data.

NITRATE IN DROUGHT-AFFECTED CORN	
PLANT PART	**NO_3-N ppm**
Leaves	64
Ears	17
Top 1/3 stalk	153
Mid 1/3 stalk	803
Lower 1/3 stalk	5524
Weighted Average	978
Walsh & Schulte, Univ. of WI, 1970	

2. Dilute high nitrate feeds with low nitrate feeds such as grain or known low-nitrate forage.

3. Remember that water may contain a significant amount of nitrate in some parts of the country. It would be best to have the livestock water tested and include that nitrate in the calculations of the total intake of the livestock.

4. Cattle and sheep can tolerate more nitrate if feeding occurs over a period of several hours.

5. Increase the carbohydrate level of the feed ration, and insure that the livestock are getting adequate levels of other nutrients.

6. Ensile the high nitrate forage if possible. Ensiling will significantly reduce the nitrate content of corn, as shown in this example :

NITROGEN APPLIED PER ACRE			
Corn Fed as:	**0 lb.**	**200 lb.**	**800 lb.**
Green Forage			
Nitrate	602 ppm	2,319 ppm	4,438 ppm
Silage			
Nitrate*	380 ppm	1,468 ppm	2,861 ppm
% decrease w/ensiling	37%	41%	36%
pH	3.9	3.8	3.8
*Nitrate values on dry basis. To convert values from ppm to percent, move decimal point 4 places to left (602 ppm = 0.06%)			
Purdue University			

7. If necessary, further silage nitrate reduction can be obtained by adding not more than 20 lb. of limestone per ton going into the silo. While limestone tends to raise pH, which in turn, can reduce silage quality, work at Purdue found that up to 20 lb. per ton was not a significant problem when other proper ensilage practices were used.

8. Introduce the high nitrate forage to the livestock gradually, over a period of several days.

NITRATE LEVELS IN CORN GRAIN

Analysis of corn grain in a study at Purdue Univ. indicated that grain is not a significant source of nitrate. Nitrogen fertilization increased the crude protein concentration from 8.69 to 9.41 percent while the nitrate-N only ranged from 35 to 64 ppm. In addition to the low nitrate N content, grain is also a source of carbohydrates and as such can help offset some of the negative effects of high nitrate forage.

EFFECT OF N FERTILIZATION ON PROTEIN AND NO_3-N IN CORN GRAIN		
N APPLIED PER ACRE	**CRUDE PROTEIN***	**NO_3-N***
0 Lb	8.69%	48 ppm
200 Lb	8.53%	35 ppm
800 Lb	9.41%	64 ppm
Purdue		* Dry weight basis

SILO GAS

Ensiling high nitrate forage can produce a poisonous nitrogen gas, reddish in color and highly toxic to man and animals. The danger of “silo gas” exists from ensiling time to about 1 week later. Therefore, during this period, do not enter a silo without first running the blower for a few minutes or using some other means to insure adequate ventilation.

SAMPLING SILAGE CORN FOR NITRATE ANALYSIS

Sampling is a rather straight-forward procedure. The sample should represent the plant material that will be fed to the livestock. This means that…

1. Select about 10 plants that represent the majority of the field to make 1 sample. Where extreme size variation exists, it would be preferable to either take multiple samples from a field, or attempt to make the plants in the sample group somewhat proportional to the field conditions.
2. The plants should be cut off at about the same height as the expected harvest cutting height.
3. The entire plant above the cutting height, including the ear, should be chopped into sections no larger than about 4 inches long and thoroughly mixed. This can be a time consuming task. Some people have been successful using small chipper-shredders, as sold to homeowners, to accomplish the task. If a mechanical shredder is used, be sure to clean it out between samples.
4. Spread out the sample on a clean surface and allow it to dry enough so that any moisture that remains will not soak a paper shipping container. After the sample has dried somewhat, mix up the material well and select about 1 qt. of the material to be sent to the lab.
5. Put the sample in a clean paper container for shipment to the lab. The large envelope supplied with the Spectrum Analytic Plant Analysis kit will work well. If you do not have our kit, you can use other clean paper containers, such as grocery bags, or large office envelopes. **Do Not Use a Plastic Bag**, because the high temperatures and humidity in the container will encourage sample decomposition during shipment.
6. These samples often take a day or two longer to process, due to the typically high remaining moisture in the sample, so plan for this.

Other crop and weed species have been known to accumulate high nitrates during drought or at other times. While they may not be a factor with silage corn, they may be significant some other time. A list of known nitrate accumulators is shown below.

NITRATE ACCUMULATING PLANTS		
Plant species most likely to accumulate toxic levels of Nitrate		
Field Crops		
alfalfa	fescue	Soybean
barley	millet	Sudan
canola	oats	Wheat
corn	rye	
Weeds		
bindweed	elderberry	pigweed
blue-green algae	fiddleneck	ragweed
bull thistle	fireweed	Russian thistle
burdock	goldenrod	smartweed
Canadian thistle	Johnson grass	stinging nettle
careless weed	jimsonweed	sunflower
cheese weed	lambsquarter	velvet weed
dock	nightshades	White cockle
Vegetables		
beets	lettuce	spinach
celery	mangles	squash
cucumbers	parsnips	Swiss chard
kale	radishes	turnips
Sources: "Nitrate Poisoning of Livestock", Guide B-807, C.D. Allison, New Mexico State Univ. "Nitrate Toxicity", N.R. Hartwig and S.K. Barnhart, Iowa State Univ.		