



PRUSSIC ACID, NITRATE POISONING AND GRASS TETANY IN BEEF CATTLE

by Eddie Funderburg, Ed.D.

This document is an attempt to consolidate information from different sources on prussic acid, nitrate poisoning and grass tetany in beef cattle. The purpose is to have a somewhat comprehensive compilation of information from various sources on the subjects to inform beef cattle producers about these topics and provide management tips to help protect their herds. None of the information was developed from research by the author.

Prussic Acid

Prussic acid poisoning can occur in animals grazing certain plants at certain

times. Plants of the *Sorghum* genus present the highest prussic acid potential, and ruminant animals are more likely to be affected than simple stomach animals. Knowledge of the process can reduce the likelihood of livestock death from prussic acid poisoning.

HOW DOES PRUSSIC ACID FORM?

Prussic acid is also known as hydrocyanic acid (HCN) or cyanide. Prussic acid toxicity in grazing animals occurs when they graze plant parts high in the toxin more quickly than their bodies can metabolize it. Hydrocyanic acid is bound in plants to a molecule called dhurrin. By itself, dhurrin is harmless. However, another

GENERALIZED RANKING OF SORGHUM TYPES BY THEIR POTENTIAL HCN ACCUMULATIONS. FROM OKLAHOMA COOPERATIVE EXTENSION SERVICE PSS-2094

Forage Types	HCN Potential
Piper variety sudangrass	Low
Sudangrass	Fairly low
Sorgo/Sudangrass hybrids	Intermediate
Sorghum/Sudangrass hybrids	High
Sorgos	Intermediate to high
Grain sorghum	High to very high
Johnsongrass	Generally high
Sorghum alum (Columbus grass)	Generally high

er compound is present in the plant called emulsion. If dhurrin and emulsion come into contact with each other, hydrocyanic acid (cyanide) is formed.^{7, 10, 12, 15}

This is usually not a problem because the two products are compartmentally separated in plant cells. Problems arise when conditions cause the two products to meet. This can be done by trampling, animals chewing on the plant, or plant cell walls rupturing by freezing or drought damage.^{10, 12, 15}

WHICH ANIMALS ARE MORE LIKELY TO SUFFER PRUSSIC ACID POISONING, AND WHY?

Ruminant animals, such as cattle and sheep, are more likely to suffer prussic acid poisoning than simple stomach animals, such as horses and swine. This is due to the chemistry and flora of the stomach. The rumen is neither strongly acidic nor alkaline, and contains a large flora of microorganisms and enzymes. This provides an excellent medium for hydrolysis of HCN. In a simple stomach animal, hydrochloric acid in the stomach reacts with HCN to create formic acid and ammonium chloride. These products are less toxic to animals than cyanide.^{7, 15}

WHICH PLANTS CONTAIN PRUSSIC ACID?

The most common plants that contain prussic acid are those in the Sorghum genus. These include sudangrass, sorghum (grain, forage, and syrup types), sorghum/sudan hybrids, johnsongrass, sorghum alum, and shattercane.^{7, 9, 10, 12} In addition, certain fruit trees, such as apricot, peach, cherry, chokeberry, apple, elderberry and wild black cherry contain prussic acid. However, livestock do not usually graze

large quantities of leaves from these trees, and they are usually not a problem.⁷ ⁹ There was one instance in Texas, in 2012, where Tifton 85 bermudagrass was found to contain toxic levels of prussic acid. The reason given was that Tifton 85 is a cross between stargrass and bermudagrass, and that stargrass can contain prussic acid in rare instances.⁵

Not all plants with prussic acid contain the same concentration. Sudangrass contains comparatively low levels of prussic acid, although very young regrowth can contain enough prussic acid to kill livestock if they eat large amounts. Sorghum contains much higher levels of prussic acid than sudangrass. Sorghum/sudangrass hybrids contain intermediate levels of prussic acid. Johnsongrass, sorghum alum and shattercane can be very high in prussic acid under conditions that favor its abundance.^{9, 12, 15}

Within species that accumulate prussic acid, there may be differences between varieties. For example, “Piper” variety of sudangrass is said to contain less prussic acid than most sudangrass varieties.¹² Ask a seed dealer if low prussic acid varieties of crops in the Sorghum genus are available.

DO ALL PLANT PARTS CONTAIN EQUAL AMOUNTS OF PRUSSIC ACID?

Prussic acid is more concentrated in leaves than in leaf sheaths or stems. Younger leaves in the upper part of the plant can contain 2 to 4 times higher concentration of prussic acid than older leaves and stems.^{12, 15} Prussic acid poisoning in cattle is often associated with new regrowth after drought or light frost. This is due to two reasons. One, rapid growth caused by rainfall or warm weather caus-

es rapid cell division in the plant. This increases the likelihood of higher prussic acid conditions. Also, the regrowth will be much more palatable to livestock, and they will preferentially graze the younger leaves, which are much higher in prussic acid than the entire plant.¹¹

WHAT ARE THE SYMPTOMS OF PRUSSIC ACID POISONING?

Hydrocyanic acid (prussic acid) combines with hemoglobin in the blood to form cyanoglobin. Cyanoglobin prevents the body cells from receiving oxygen from the blood, so animals die of asphyxiation, or oxygen deprivation. Symptoms may occur within five minutes of eating affected forage, and death can occur within 15 minutes. Symptoms include excitement, increased respiration rate, labored breathing, foaming at the mouth, twitching and spasms, and a blue coloration of the lining of the mouth. Affected animals often lie down and thrash about. The blood of affected animals will be bright red, compared to the chocolate brown color in animals suffering nitrate poisoning.^{2, 4, 9} Symptoms are often not observed since death occurs very soon after ingesting affected forage.^{7, 9, 10, 11, 12, 15}

CAN PRUSSIC ACID POISONING BE TREATED?

Prussic acid poisoning in livestock can be successfully treated but is difficult to accomplish since animals die quickly after ingesting a toxic dose. Treatment consists of sodium nitrate and sodium thiosulfate. The sodium nitrate induces a degree of nitrate poisoning, which is simultaneously treated with sodium thiosulfate. The sodium thiosulfate cures the toxic condition and allows the blood to transport oxygen normally.^{7, 10}

CAN I TEST FOR PRUSSIC ACID IN MY FORAGE?

There are two types of tests for prussic acid in forages. One is the quantitative method. This method requires laboratory equipment and reports the concentration of HCN (prussic acid) in the plant material tested. This method provides the most useful information. Another type is the qualitative method. This method reveals whether or not HCN is present, but cannot quantify the concentration of HCN in the plants.

Collecting a representative sample is

important in either type test. This is very difficult because all plants in the field do not contain similar concentrations of HCN, and the levels are dynamic and subject to fairly rapid change. The tests only measure the concentration of the plants sampled at the time they were sampled. Conditions may have changed by the time test results are analyzed.

Sampling procedures are the same for either method. Collect the uppermost new leaves of 10-12 plants in different areas of the field. Place the leaves into a sealable container (usually a sealable plastic bag), and place the container on ice. DO NOT FREEZE the container.^{9, 11}

If you want the quantitative analysis done, ship or deliver the samples to the laboratory as soon as possible. The lab will conduct the analysis and provide a report with the amount of HCN in your plants. The following table can be used to determine if your plants contain enough HCN to be harmful to livestock.¹²

The qualitative analysis is easier to conduct, but only tells whether or not HCN is present. It does not give a concentration of the toxin. This method uses cyantesmo paper to determine if HCN is present. The collected forage sample is brought in an airtight plastic bag to someone who has cyantesmo paper. A piece of the test paper is placed in the bag. If cyanide is present, the paper will turn blue within five minutes. Some extension agents and retail agricultural suppliers have cyantesmo paper and test forage when environmental conditions favor prussic acid development.¹²

IS PRUSSIC ACID A PROBLEM IN HAY?

Prussic acid should not be a problem in well-cured hay. Prussic acid content decreases as much as 75 percent during the hay curing process and is rarely a problem when fed to livestock.¹⁰ If hay is baled too green and not cured properly, there is a greater chance of prussic acid poisoning.

WHAT MANAGEMENT PRACTICES CAN I USE TO REDUCE THE PROBABILITY OF PRUSSIC ACID POISONING?

There are several steps a livestock producer can take to reduce the risk of losing livestock to prussic acid poisoning. These include:

- Do not graze forages that are prone to

GENERALIZED INTERPRETATION FOR FORAGE PRUSSIC ACID (HCN) TEST. FROM OKLAHOMA COOPERATIVE EXTENSION SERVICE PSS-2094

ppm HCN (dry matter basis)	Interpretation
0 - 250	Very low - safe to graze
251 - 500	Low - safe to graze
501 - 750	Medium - doubtful to graze
751 - 1,000	High - dangerous to graze
>1,000	Very high - very dangerous to graze

develop prussic acid when they are immature. Wait until sorghum and sudan grasses are at least 18 inches tall to graze. Prussic acid is most prevalent in the youngest plant tissues. Grazing larger plants gives a higher likelihood that livestock will graze both mature and immature plant tissue, thus diluting the prussic acid concentration they ingest. A 1,000-pound cow can safely detoxify HCN at a rate of about 0.5 grams per hour.^{7, 12, 15}

- Do not introduce hungry livestock into a field containing forages prone to prussic acid development. Feed hay before turning livestock into such a field, and preferably turn them in late in the afternoon so they will not eat these forages all day. Hungry livestock may consume more HCN than their bodies can detoxify.^{7, 12, 15}
- Choose varieties of sorghum or sudan grasses that contain lower amounts of

HCN, if possible.¹²

- Remove cattle from fields with plants that can develop prussic acid during times of rapid regrowth after injury. Examples are rapid plant regrowth after drought or frost. The new growth at these times can be extremely high in HCN. Do not return cattle to these fields until the regrowth is at least 24 inches tall following a drought or until the plants are dry after a killing freeze.^{7, 10, 12, 15}
- Fertilize according to soil test recommendations. Prussic acid levels are often higher in plants grown on soils that are deficient in phosphorus and/or potassium, and that were fertilized with only nitrogen.^{10, 12}
- Harvest forages for hay or silage instead of grazing if they are suspected to be high in prussic acid.

Nitrates

WHY DO PLANTS ACCUMULATE EXCESSIVE LEVELS OF NITRATES?

Nitrogen is an essential element for plant growth and development. One form of nitrogen that plants take up through the roots is nitrate. It is usually the most abundant form of nitrogen taken up by plants. When plants are growing normally, they convert nitrate to amino acids and proteins quickly enough that toxic levels of nitrates do not accumulate in the plant. However, when plants are stressed, the conversion of nitrate to protein slows, and nitrates can accumulate in the plants to levels that are toxic to animals that eat them.^{2, 4, 9, 11}

HOW DO EXCESSIVE LEVELS OF NITRATES IN PLANTS HARM ANIMALS?

In the animal's rumen, microbes convert nitrates (NO_3^-) to nitrites (NO_2^-). Nitrites are converted to ammonia (NH_3), which is converted to protein. When animals ingest excessive levels of nitrates, nitrite can accumulate faster than it can be converted to ammonia. Nitrites are then absorbed into the bloodstream and convert hemoglobin to methemoglobin. Methemoglobin cannot transport oxygen. Therefore, the animal suffers from lack of oxygen due to nitrite poisoning. Animals can ingest excessive amounts of nitrate by eating feeds and forages high in nitrate, drinking water high in nitrate, or eating fertilizer containing nitrates.^{2, 4, 13, 14}

WHAT ARE THE SYMPTOMS OF NITRATE POISONING IN CATTLE?

Early and chronic symptoms of nitrate poisoning include watery eyes, reduced appetite, reduced milk production, rough hair coat, weight loss, night blindness, and abortion. Symptoms of acute nitrate poisoning include accelerated pulse rate, labored breathing, muscle tremors, weakness, staggering gait, cyanosis (tongue, mouth, vulva, and whites of eyes turn blue), and death.⁴ The blood of affected animals will be chocolate brown, compared to the bright red blood from animals suffering prussic acid poisoning.^{2, 4, 9} Death may occur within one hour, or in the usual case, within three to four hours of the onset of difficult breathing.²

CAN NITRATE POISONING IN ANIMALS BE TREATED?

Nitrate poisoning can be treated, but the treatment must be administered

in a timely manner. Since death occurs fairly soon after the onset of acute symptoms, this may be difficult. A veterinarian can administer an intravenous dose of methylene blue. This converts methemoglobin to hemoglobin and increases the oxygen carrying capacity of the blood. The treatment may need to be repeated since absorption of nitrate into the bloodstream can continue from a full rumen.^{2, 4}

WHAT ENVIRONMENTAL FACTORS INFLUENCE NITRATE ACCUMULATIONS IN PLANTS?

Generally speaking, anything causing stress in plants, with a resulting decrease in plant growth, increases the potential for nitrate accumulation. Some of the factors are:^{2, 3, 4, 9, 13}

- Lack of sunlight – poor photosynthesis slows the conversion of nitrates to protein.
- Abnormally hot or cold temperatures – dramatic changes in temperatures slow plant growth and slow the conversion of nitrates to protein.
- Drought – dry conditions slow plant growth.
- Herbicide damage – can cause severe stress in plants and can inhibit photosynthesis.
- Plant diseases and insects – can damage photosynthetic pathway and also slow growth.
- Excessive rates of nitrogen fertilizer.

WHICH PLANTS ARE MORE LIKELY TO ACCUMULATE TOXIC LEVELS OF NITRATES?

All plants accumulate some nitrates, but certain types of plants are more likely to accumulate toxic levels. Some plants generally thought of as weeds accumulate toxic levels of nitrates. These include pigweed, lambsquarters, ragweed, velvetleaf, some thistles, docks, jimsonweed, johnsongrass, kochia, smartweed, sunflower and many nightshades. Crop plants that are known to accumulate toxic levels of nitrates include alfalfa, barley, corn, fescue, oats, rescuegrass, rye, sorghum, sudangrass, wheat and pearl millet.^{2, 9, 13}

GENERALIZED RATING OF SOME FORAGE GRASSES AND FORBS BY THEIR NITRATE ACCUMULATION POTENTIAL. FROM OKLAHOMA COOPERATIVE EXTENSION SERVICE PSS-2903

High potential	High potential	Low potential
Grasses	Forbs	
Barley	Horsenettle	Bermudagrass
Bromegrass	Kochia	Buffalograss
Corn	Lambsquarter	Gramagrass
Fescue	Morning glory	Weeping lovegrass
Johnsongrass	Pigweed	Bluestems
Oats	Puncture vine	
Rescuegrass	Russian thistle	
Rye	Sunflower	
Sorghum		
Sudangrass		
Wheat		
Pearl millet		

DO NITRATES OCCUR IN HIGHER CONCENTRATIONS IN CERTAIN PARTS OF PLANTS?

The highest concentration of nitrates in plants occurs in the lower stalks and stems. Nitrates are progressively diluted toward the top of the stem. Little nitrate is found in flowers and seeds.^{2, 3}

NITRATE NITROGEN IN 28 SAMPLES OF DROUGHT-STRESSED CORN. FROM CASSEL ET AL., 2012

Plant Part	ppm Nitrate-Nitrogen
Leaves	63
Ears	17
Upper 1/3 of stalk	153
Middle 1/3 of stalk	803
Lower 1/3 of stalk	5,524
Whole plant	978

HOW DOES NITROGEN FERTILIZER RATE AFFECT NITRATE ACCUMULATION IN PLANTS?

If the plant is growing normally, recommended rates of nitrogen are unlikely to cause an accumulation of toxic levels of nitrates. When conditions favor nitrate accumulation, nitrates can, and often do, accumulate in plants which have not been fertilized. However, overfertilization with nitrogen can exacerbate the situation if conditions favor nitrate accumulation. The following tables show how N rates and

harvest management can influence the accumulation of nitrates in plants.

AVERAGE NITRATE CONCENTRATIONS (PPM) OF HYBRID SUDANGRASS HAY GROWN UNDER DIFFERENT NITROGEN FERTILIZER SCHEMES. FROM OKLAHOMA COOPERATIVE EXTENSION SERVICE PSS-2903

*Nitrogen Rate (lb/ac)(ppm)	Nitrate Concentration
0	3,631
50	6,282
100	6,098
150	7,083
200	8,432

*Applied at planting and after each harvest

DOES HARVESTING FORAGE AS HAY OR SILAGE DECREASE NITRATE CONCENTRATION?

Nitrates do not decrease in the haying process. However, nitrates are highest in plants in the early morning and decrease throughout the day. Therefore, hay cut in the afternoon on a sunny day should have somewhat fewer nitrates than hay cut in the morning. Raising the cutter bar will also reduce nitrate levels since nitrates concentrate in the lower parts of plants.

Nitrates do decrease in the ensiling process. The amount of reduction is usually

NITRATE ACCUMULATION VARIES WITH FORAGE TREATMENT AND FERTILIZATION MANAGEMENT. FROM MONTANA STATE EXTENSION MT200205AG REVISED 3/15

Description	Crop	Variable	Nitrate (ppm)
Nitrates decreased as plants mature	Oat	Heading	5,047
		Flowering	4,726
		Soft dough	3,027
Plant parts vary in nitrates	Oat	Stems	8,000
		Leaves	4,200
		Heads	1,000
Nitrates increase with high N fertilization	Oat stems at boot stage	50 lb N/ac	6,000
		100 lb N/ac	8,000
		150 lb N/ac	12,500
Ensiling tends to decrease nitrates once fermentation is complete	Corn with 200 lb N/ac	Green forage	2,319
		Silage	1,468

in the 20-40 percent range. It takes about four weeks for the nitrate reduction to be complete. Raising the cutter bar on the silage harvester will also decrease the nitrate concentration in the silage.

EFFECT OF ENSILING ON NITRATE CONCENTRATION IN CORN SILAGE. FROM CASSEL ET AL., 2012

	N applied (lb/ac)		
	0	200	800
Nitrate ppm green forage	602	2,319	4,438
Nitrate ppm green silage	380	1,468	2,861
% decrease by ensiling	37	41	36

WHAT MANAGEMENT PRACTICES CAN I USE TO PREVENT NITRATE POISONING IN MY LIVESTOCK?

- Understand the environmental conditions that favor excessive nitrates in plants, and plan grazing accordingly. Avoid fields that have plants known to accumulate nitrates when these conditions exist, and graze fields containing plants that are less prone to accumulate nitrates.¹³

- Cut hay or silage higher than normal. Nitrates accumulate in the lower portions of the plant. Cutting the plants higher may “waste” some forage, but it is better than losing cattle to nitrate poisoning.^{2,13}

- Follow soil test recommendations. Do not overfertilize with nitrogen, and apply lime, phosphorus, and/or potassium if

recommended.^{4,13}

- Do not turn hungry animals onto fields with plants suspected of being high in nitrates. Hungrier animals will consume more forage and ingest more nitrate.¹¹

- Control weeds. Some weeds accumulate higher levels of nitrates than forage crop plants.⁴

- Ensile crops that have high nitrate levels, if possible. The ensiling process can reduce the nitrate level by 20-40 percent.^{2,9,11,13}

- Test forages if they are suspected to have accumulated high levels of nitrate.^{2,4,9,11,13}

- Propionibacterium products such as Bova-Pro® are available in bolus or powder form that are reported to reduce nitrate and nitrite levels in the rumen by approximately 40 percent. These products must be established in the rumen for at least 10 days before allowing cattle to consume high nitrate feedstuffs.

HOW DO I TEST MY FORAGES TO DETERMINE IF THEY ARE HIGH IN NITRATE?

Nitrates can be accurately analyzed in forage and hay, but proper sampling is difficult because nitrates are highly variable across fields. Isolated areas in fields may contain much more nitrate than most of the field. Likewise, a few bales of hay may contain very high nitrate levels, while most of the bales are safe. Oklahoma State University noted a 5-acre sorghum/sudan pasture that had nitrate concentrations

ranging from 7,930-43,600 ppm. To sample grazing fields, try to minimize sampling error by clipping at least 20 representative plants across the field at grazing height. Cut the plants into two-to three-inch sections, combine them and mix thoroughly in a clean bucket.¹³ To sample hay, collect one core per bale from 20 small square bales, or two cores per bale from 10 large square or large round bales.¹³

Nitrates can be detected with field tests or laboratory tests. A common field test uses diphenylamine. This test is rapid (about five seconds to determine if nitrates are present) but does not quantify the concentration of nitrates in the plant. It is useful as a screening process. If this test shows the presence of nitrates in plants, they should be sent to a laboratory to determine the concentration present.^{3, 4, 9, 13} Results from a laboratory can sometimes

be confusing. Some report the results in terms of the concentration of nitrogen as nitrate (nitrate-nitrogen), while others report the concentration of nitrate. Some labs may report in terms of percentage, and others parts per million (ppm) nitrate or nitrate-nitrogen. The following table shows the conversion equations.¹⁴

Grass Tetany

Grass tetany is a disorder caused by a magnesium deficiency in ruminant grazing animals. It usually occurs in lactating cows with young calves and is often associated with grazing cool-season annual grasses. Cattle grazing young grasses are at more risk than animals grazing mature foliage. The disorder can be exacerbated by cool, cloudy weather and by overfertilization with nitrogen and potassium.^{1, 6, 8}

FROM UNDERSANDER ET AL., NITRATE POISONING IN CATTLE, SHEEP AND GOATS

Converting from nitrate to another form		
Reported as	Converted to	
Nitrate-Nitrogen (NO ₃ -N)	Nitrate (NO ₃)	Multiply by 4.4
Nitrate (NO ₃)	Nitrate-Nitrogen (NO ₃ -N)	Multiply by 0.23
Percent (%)	Parts per million (ppm)	Move decimal point four places to right
Parts per million (ppm)	Percent (%)	Move decimal point four places to left

When lab results have been received, the following table can be used to determine the relative toxicity of the forage that has been tested.¹³

GENERALIZED INTERPRETATION FOR FORAGE NITRATE TEST. FROM OKLAHOMA COOPERATIVE EXTENSION SERVICE PSS-2903

ppm Nitrate (NO ₃) dry matter basis	Interpretation
0-3,000	Generally safe for all cattle
3,001-5,000	Generally safe for non-pregnant beef cattle. Low risk of reduced breeding performance and early term abortions. Total ration for dairy cattle should be less than 2,500 ppm NO ₃ .
5,001-10,000	Some risk for all cattle. May cause mid-to late-term abortions and weak newborn calves. May decrease growth and milk production.
>10,000	Potentially toxic for all cattle. Can cause abortions, acute toxicity symptoms and death.

WHAT ARE THE SYMPTOMS OF, AND TREATMENT FOR, GRASS TETANY?

Symptoms include grazing away from the herd, nervousness, lack of coordination, muscle spasms, staggering, head thrown back, thrashing and death.^{1,8} Cattle often die within four to eight hours of the onset of symptoms, so dead cattle may be the first symptom seen unless the cattle are under very close supervision.

Treatment is an intravenous injection of magnesium and calcium in a dextrose base. Treatment can be effective if administered within one to two hours of the onset of symptoms. However, that can be difficult to accomplish in a pasture situation.¹

HOW CAN I PREVENT GRASS TETANY?

There are several ways to prevent, or reduce the severity of, grass tetany in a herd. These include:

- Avoid grazing cattle on young winter annual pastures until the grass is at least 6 inches tall because magnesium is less available in immature plants.^{1, 6, 8}
- Graze less susceptible animals on high risk pastures. Heifers, dry cows and stockers are less likely to develop grass tetany than are lactating cows.¹
- Do not overfertilize pastures with nitrogen and potassium. Use dolomitic limestone if soil test recommendations indicate the need for lime.^{1, 6}
- Incorporate legumes into winter annual grass pastures. Legumes contain higher concentrations of magnesium than grasses.¹
- Feed a mineral and/or supplement high in magnesium. Commercial high magnesium mineral mixtures typically contain 10-15 percent magnesium.^{1, 6, 8}
- If possible, add a soluble magnesium salt to the water supply.⁶

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