Science Societies

Researchers question science, testing methods for prussic acid (HCN) in forages

By Tanner Ehmke

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Bagged forage sample (left) and mature forage sorghum (right). Photos courtesy of Fred Vocasek.

Livestock and forage researchers are rethinking the science behind prussic acid, or hydrogen cyanide (HCN), in livestock feed. The advice that always has been promoted to crop and livestock producers for managing HCN toxicity risk in forages may not be supported by sound science.

While it's common knowledge that prussic acid, or hydrogen cyanide (HCN), can be a toxic problem in forages, especially within the sorghum species, researchers across the High Plains have become skeptical in recent years based on anecdotal evidence and field observations. Often-repeated recommendations on managing and testing for HCN, they argue, may be based more on dogma and tradition than data.

"There are a lot of unanswered questions," says Dr. Jourdan Bell, agronomy specialist for the High Plains Region at Texas A&M. "Given the anecdotal evidence, perhaps we don't know as much as we thought we did. HCN is showing up in places you wouldn't expect, and it's not consistent across species. Perhaps it requires more research trying to pinpoint how, when, and where it shows up."

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More than 2,500 plant species produce significant quantities of cyanogenic glycosides that can be converted to HCN in the plant or rumen. In sorghum species, dhurrin is the cyanogenic glycoside that dhurrinase—the most common enzyme present in sorghum—synthesizes into HCN and creates potential toxicity for livestock. In the sorghum family, dhurrin serves as a potential defense against insects, a possible reduction in herbivore activity, and a potential nitrogen storage sink in the plant.

Bale and windrows in a field of forage sorghum. Also visible are small regrowing plants that are high in prussic acid. Photo courtesy of

Fred Vocasek.

The factors affecting accumulation of dhurrin and other cyanogenic compounds in the plant are wide-ranging and include genetics, plant maturity, water stress, nitrogen, and other factors.

However, researchers are rethinking what drives dhurrin content in a plant and its conversion to HCN.

Jason Banta, beef cattle specialist at Texas A&M AgriLife Extension who has spent years consulting producers on forages, points out that in most journal papers published in the last 30 years, frost is not mentioned as a factor affecting dhurrin content in plants.

Anecdotal evidence across the High Plains also brings to question a frost's true impact on HCN levels in forages.

"In 2018, we had a dry spring and early summer. And once it started raining, it wouldn't stop, and producers just couldn't get into their fields to cut their hay. A lot of those hay fields didn't get cut until November, December, even January," Banta explains. "So at that point in time, we had a lot of producers who had heard you've got to stay away from sorghums or johnsongrass after a frost because of the perception of higher risk of hydrogen cyanide. But there were some of us in extension who, based on our experience of grazing cattle after a frost and never having any problems, weren't so confident that was accurate, but we didn't have any data to share with producers."

Because of all the unanswered questions related to Johnsongrass, Banta and colleagues in the animal science department received a small grant from Texas A&M to research HCN potential in Johnsongrass. Banta started sampling Johnsongrass the following summer every two weeks in three locations around the state, and sampled at

various plant heights. Plant samples were taken immediately before and after a frost, with some samples tested multiple weeks later. The preliminary data from those samples indicated HCN risk potential decreased as plants matured and was lower after the frost than before, Banta says.

However, Banta points out that recent research at Purdue documented an increase in HCN potential after a frost in conventional sorghum–sudangrass hybrids. There is more to learn, Banta stresses, and there are several potential reasons for the differences in recent findings, including perennial versus annual plants, geographical location, killing versus non-killing frosts, and sampling of the whole plant versus a punch sample of part of the leaf, Banta added.

Bell also noticed inconsistencies in field samples with HCN showing up in peculiar places in drought conditions.

“Last year, I was doing some cover crop work with one of our county agents and a producer, and he had a crabgrass pasture interseeded with sorghum–sudans and all these different mixes,” Bell explains. “I sampled everything exactly the same, and to my surprise, the crabgrass came back with HCN and the sorghum–sudans didn’t. It’s just odd, and I don’t think we know enough to really answer why.”

HCN Risk in Hay

Inconsistent results from forages that have been swathed and hayed have also raised red flags with researchers.

Dr. Sandy Johnson, extension livestock specialist at Kansas State University, notes that literature on HCN has always advised that HCN gas dissipates quickly as plants dry down during the hay-drying process following a freeze. But in 2019, a Kansas livestock producer reported losing seven cows from eating sorghum–sudan hay that contained

moderate levels of HCN. The incident prompted Johnson to review the scientific literature behind HCN and start asking questions.

“We’re always learning more,” Johnson stresses. “I think one of the challenges with HCN is that it seems to be so variable, and there are so many factors impacting when we actually see problems with it or not. We may not have had a broad enough look in trying to figure it out.”

In Texas, Bell has also observed cattle dying from HCN poisoning after eating baled forage that should have been nontoxic, based on the conventional wisdom that potential toxicity quickly dissipates over time. The lack of data supporting that theory and the real-world observations that run counter to it leaves many questions unanswered, Bell says.

Calves on dhurrin-free sorghum. Photo by Dr. Keith Johnson, Scholer Beef Farm, Purdue University, 2021.

Banta echoed similar concerns with HCN content in hay, pointing out that cutting and baling Johnsongrass for hay was commonly thought to result in plant tissues breaking down allowing dhurrin to be converted into HCN and dissipate. Preliminary research conducted by Banta and colleagues at Texas A&M instead indicates that some dhurrin remains in the dried forage and can be converted to HCN at a later time.

“The majority of the hay that is produced is likely not at risk at all, but there is some that may have levels that may be concerning,” Banta advises. “It’s really going to depend on the levels, on the animals, how much they consume, and how quickly they consume it.”

Species and Cultivars

Differences between the wide variety of plant species and cultivars in how the plants respond to differences in geographical locations and environmental conditions add another layer of complexity to the management of sorghums and other plants at risk of HCN toxicity, he notes.

Available literature indicates that plant genetics definitely has an impact on HCN potential, Banta says.

Further complicating research and forage management is how variability in weather conditions can influence HCN levels across the spectrum of forage species and varieties, Johnson adds.

"The wide range of freeze and frost conditions even within a given field make it challenging to study," Johnson points out. "HCN potential does seem to increase under some freeze and frost conditions, but it likely depends on nature of the weather change over several days, like continued cold temperatures, or cold conditions one night followed by well-above freezing conditions for a week or more."

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Banta notes that a solution to HCN risk may be on the horizon. Seed companies and universities are now working on dhurrin-free or low-dhurrin sorghum, which researchers will be evaluating in the field this year.

At Purdue University, plant breeders recently developed sorghum–sudan hybrids that are free of dhurrin and don't produce HCN and are therefore safer for grazing animals like cattle and sheep. Researchers at Purdue are working with AgAlumni Seed Company and S&W Seed Company to commercialize these products.

This frost-damaged Johnsongrass is perceived to have a higher risk of hydrogen cyanide (HCN) by many producers. However, Jason Banta, beef cattle specialist at Texas A&M

AgriLife Extension, points out that in most journal papers published in the last 30 years, frost is not mentioned as a factor affecting dhurrin (the cyanogenic glycoside that is synthesized into HCN in sorghum species). University of Arkansas System Division of Agriculture photo by John Jennings.

Dr. Mitch Tuinstra, professor of plant breeding and genetics at Purdue University, says that the new hybrids perform well with grazing animals like sheep and cattle.

"We've been testing dhurrin-free sorghum–sudan hybrids for the past few years, and new photoperiod-sensitive hybrids are becoming available as well. These were developed for grazing and hay production," Tuinstra explains. "The intent would be for these prototypes to be grazed in the field. Dhurrin-free forage and grain sorghum hybrids are also being developed and evaluated to explore new forage management systems and opportunities."

The Purdue research team will be publishing the results from the feeding trials of dhurrin-free sorghum hybrids with cattle later this year, Tuinstra says.

Discrepancies in Testing

Differences in lab-testing methods of forage samples have added to the uncertainty around how to manage for HCN and understand toxicity risk to livestock.

"The testing procedures that the lab uses can change the results we see," Banta explains. "We can take and send subsamples of the same sample to different labs and get different results because of the methodologies."

One of the most important differences in lab analysis, Banta points out, is if a beta-glucosidase enzyme is added in the testing process or not.

"Beta-glucosidases are key enzymes that help convert dhurrin in the plant to hydrogen cyanide. However, at times there may not be enough beta-glucosidase enzyme in the

plant to convert all the dhurrin or other cyanogenic glucoside to HCN when it is being tested. To get a more accurate measurement of HCN potential, some labs will include additional beta-glucosidase enzyme as part of their analysis, but most of the labs do not," he says. "So, if we don't have enough enzyme in there, that will affect the results and cause them to be lower than they should be. I've sent in subsamples to have the lab run them both with and without the added enzyme. The results come back significantly lower if the additional enzyme is not included."

Johnson adds that some labs do not measure dhurrin and instead use different means to estimate how much HCN can be released. Further, the rate of release of HCN appears to vary depending on if the sample is fresh or dried, she explains.

"Since there are variations in testing procedures, it's important that if someone is going to have forage samples tested, they have an understanding of the methodology that the lab is using and how that may or may not impact their results. Samples for our work have been analyzed by ServiTech Laboratories in Amarillo," Banta says. "Based off of some recent samples that Dr. Bell, myself, and other colleagues have had tested, I would encourage folks to consider testing for both nitrates and HCN potential if they suspect there might be a problem with one or the other. We were mainly interested in looking at HCN potential of these samples but went ahead and analyzed for nitrates as well just to check. Some of the samples had high levels of nitrates that we were not expecting," he adds.

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However, just because a plant has hydrogen cyanide potential does not mean it's a high-risk plant, Banta notes. Dhurrin content can increase due to environmental conditions or management practices and still be in a non-toxic range.

"There's a good chance we have some level of hydrogen cyanide potential in a lot of plants, but it's just at a low level," Banta says. "There are certain times under certain conditions where we have some forages that end up accumulating much higher levels of dhurrin than normal, and that's when we can get into some problems."

Researching and Managing HCN

The dearth of research behind HCN raises new questions for researchers and CCAs advising farmers and ranchers on how to manage HCN toxicity risk. Banta advises everyone to keep an open mind and realize that recommendations may change with more research, experience, and changes in plant genetics.

“We have to really look at the literature we have now and make sure the recommendations we’re making are based off of the currently available literature and not just perception of what the situation is,” Banta stresses. “And as with most things, it takes time and research, and there are people looking at it. But one of the big challenges is when it comes to forage research in general, there’s just very limited funding to do that research.”

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