While lime applications are nothing new in the Midwest where acidic soils are the norm, the western Wheat Belt where soils are predominantly alkaline, or basic with pH above 7, is facing a similar challenge on an increasing scale as pH drops over time. Low pH can reduce crop performance by negatively affecting nutrient uptake from plants, legume nodulation, residue decomposition, and herbicide breakdown and carryover.

Soil acidification, or the increased concentration of positively charged hydrogen ions (H+) as measured on the pH scale with 0 as acid, 14 as base, and 7 as neutral, is a process that occurs naturally through time as alkaline minerals are leached from the soil with precipitation, says Gary Hergert, a veteran soil scientist at the University of Nebraska-Lincoln’s Panhandle Research and Extension Center in Scottsbluff, NE. The higher the H+ concentration, the lower the pH. In low-rainfall areas like the Western Plains of Kansas, Colorado, Oklahoma, and Nebraska, alkaline minerals are generally in abundance compared with high-rainfall regions like the Midwest.

Rainfall itself is also a natural soil acidifier. Rain combines with carbon dioxide in the atmosphere to form carbonic acid, which accumulates in the soil and lowers pH.

By Tanner Ehmke
Crops & Soils magazine contributing writer

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But thanks to multiple generations of farmers fertilizing with nitrogen (N) and harvesting crops, this natural geologic process that normally takes thousands of years has been kicked into hyper drive, says Brian Arnall, soil scientist at Oklahoma State University in Stillwater, OK.

As crops are harvested, basic cations, which are positively charged nutrients like calcium, magnesium, potassium, are removed from the soil. The nitrification of ammonia or ammonium-forming fertilizers, meanwhile, spins off H⁺ ions into the soil, thereby increasing the H⁺ concentration and lowering pH.

The steady drop in pH across the plains is costing farmers and landowners in lost productivity, agronomists say. But pH itself doesn’t cause problems with crop health, Arnall points out. The problem is with aluminum toxicity caused by a low-pH soil environment.

“The pH itself doesn’t hurt anything. It’s what results from it, which is the release of aluminum and manganese into the soil solution to toxic level,” Arnall says, adding that aluminum toxicity is by far the greater concern with magnesium toxicity being less common.

Aluminum toxicity occurs when free aluminum that is found naturally in clay soil particles is released into the soil structure when pH falls below 5.8 and then “prunes” the root system, thereby prohibiting crops from responding to fertilizer regardless of fertility rate.

The effects of aluminum toxicity can be devastating, according to Bruce Hungerford, CCA at Rock County Agronomy Service in Bassett, NE. In situations where aluminum toxicity is severe, farmers can experience a 75 to 80% yield loss, he says.

And, the problem of acidic soils and aluminum toxicity is spreading across the Plains. In Oklahoma alone, Arnall says between 25 and 30 percent of the soil samples sent to the state soil laboratory are acidic, and most of them come from regions naturally neutral or alkaline. Soils that were pH 6.5 when they were broken out of sod generations ago are now pH 4.0.

“That’s not a 5- or 10-year process,” Arnall notes. “We’re talking about ground that has been farmed for 125 years. What you see is a long-term production system that, if not managed correctly, will result in acidification of the soil.”

Extreme drought conditions have intensified the effects of soil acidification, adds Fred Vocasek, CCA at
Features

Servi-Tech Laboratories in Dodge City, KS.

“In the mid-1980s, the problem we saw was with wheat. The soil pH was dropping slowly, but when we had adequate rainfall and a marginal soil pH, the roots would regrow as they would recover from it. But when we had dry conditions, that was the straw that broke the camel’s back. It was an additional stress the crop couldn’t recover from, and we started seeing those pH problems show up.”

Incremental drops in pH also affect crop performance more rapidly, Vocasek warns. A change of one unit on the pH scale equals a 10-fold change in H+ concentration. A soil at pH 5, then, is 10 times more acidic than pH 6, while pH 4 is 100 times more acidic than pH 6. Lowering the pH only slightly from 6.0 to 5.7 doubles acidity.

Furthermore, Arnall says, aluminum is highly soluble with a 1,000-fold change per each unit of pH. At pH 5, aluminum concentration is 27 ppm (parts per million) but jumps to 27,000 ppm at pH 4. Aluminum toxicity begins when free-aluminum concentration is 25 ppm or greater.

If soil pH falls below 5.5 and creeps to 5.3, 5.2 or lower, problems quickly develop with root systems and plant development in non-legume crops like wheat or corn, Vocasek says. For legume crops like soybeans or alfalfa, plant health is affected at around pH 6.2. The tell-tale sign of aluminum toxicity, he adds, is a stunted plant with nubs for roots that have been burned by the free aluminum.

“Under soil acidity, the free aluminum jams up the growing point on the root system,” Vocasek illustrates. “When you look at the root system of the aluminum-damaged wheat plant, it looks like you’ve taken a healthy root system and held a cigarette lighter under it. The roots get kind of nubby, and they look like they’re burned off. They aren’t fine roots.”

Another red flag is purple leaves symptomatic of phosphorus deficiency caused by free aluminum interfering with nutrient transfer at the roots. Phosphorus deficiency is similar to animals unable to consume feed, Vocasek notes, no matter how badly the animal needs the nutrients.

“The example I use is a cow with a bunch of sores in her mouth,” he says. “You can put the finest quality hay and best feed in front of her, and she’ll starve to death because she simply cannot consume that nutrient.”

But aluminum toxicity isn’t the only yield-penalizing factor with low-pH soils. Controlling weeds is also more difficult since acidic soils shorten the residual, or useful life, of the herbicide, particularly with herbicides in the triazine and sulfonylurea families.

“Acid soils cause many of our herbicides that are used in small grains to be less efficient,” Arnall says. “They degrade more rapidly.”

The breakdown of soil-applied herbicides has become more of an issue in recent years as farmers switch to alternative weed management programs because of glyphosate-resistant weeds, says Dallas Peterson, weed scientist at Kansas State University in Manhattan, KS. Soil-applied pre-emergent herbicides are of particular concern. The sulfonylurea herbicide, Glean, for example, has a half-life of 10 weeks at pH 7.5. But, at pH 5.6, its half-life drops to only two weeks.

“Generally, where we tend to see the biggest change is in the pH 6.5 to 7.0 range,” Peterson says. “When you get below 6.5, herbicide activity and persistence are reduced with atrazine and some of the sulfonylurea products.”

High-risk soils

While falling pH is a concern region-wide through the Plains, sandier soils are the most vulnerable to experiencing low pH and yield loss, agronomists say, while heavier soils are less at risk.

Sandy soils lack an abundance of clay particles, which have a negative charge and can hold onto positively charged basic cations, which are free to leach from the soil profile and lower the soil’s pH if unattached to clay particles.

“[Soil acidity] is primarily showing up on our sandier, more eroded ground such as old blown-up fence rows, sandy knobs, and hills where we’re working with shallow topsoil,” Hunderford says. “We’d like to see

Symptoms of aluminum toxicity in wheat. High concentrations of aluminum will first reduce development of the roots, giving them a stubby appearance. They will often have a brownish color. Typical symptoms in the aboveground portion of the plant are small leaves, and shortened and thickened internodes. Photo courtesy of CIMMYT.
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them in that 6.0 or 6.2 pH range. But for most of the sands around here, we’ve got a pretty good pH if we’ve see one in the 5.5 to 5.8 window. We’ve got a lot of the really sandy soils down around 5.0, and the farmer’s got to fix that if he wants to maintain his yields.”

The problem of low pH soil is generally found only in the top 3 to 4 inches of the soil profile where most of the chemistry is occurring, Hergert explains. The next 4 to 8 inches of soil will typically be closer to neutral, he says, with the subsoil being calcareous. However, soil acidification is gradually working its way downward even into the subsoil, Hungerford says of his Nebraska territory.

“Back in the 1960s and 1970s, a lot of this country had good subsoil pH. It was just a surface issue,” he says. “Now it’s transitioned from being a surface issue to a profile issue. We’re looking at sampling in a lot of cases down to 2- and 3-ft for nitrate nitrogen management, and we still have pH issues at some of those levels.”

CCAs also note that dryland fields tend to be higher risk. Since irrigated fields are often fed with groundwater that naturally contains basic cations, the soil often sees minimal drops in pH or may even see slight increases.

However, irrigated fields planted to high-yielding corn often experience higher nitrogen fertilizer rates and more crop removal, which can counterbalance the basic cations that are added to the soil from the irrigation water, Arnall says.

“It’s a big difference when we’re talking about dryland wheat production in eastern Colorado and irrigated corn in western Kansas because of the total crop removed. Twenty bushels of wheat is not removing much, but 250-bu corn removes a significant amount more calcium and magnesium,” he says. “What you also have happening in irrigated corn ground is application of nitrogen. Higher rates of nitrogen are going to convert more ammonium to nitrate and acidify the soil.”

Managing low pH

Falling pH is inevitable if crop removal and nitrogen fertilization take place, says Arnall, but farmers can still slow the acidification process through farming practices to delay lime applications.

Soil will become acidic faster and require liming more often if both grain and straw are harvested in a wheat crop, he says, but leaving straw can return basic cations back to the soil and slow acidification. Arnall also recommends soil testing and applying N very accurately to reduce the risk of unused N contributing to soil acidification.

Farmers can also plant crops with aluminum tolerance. Species like fescue and blueberries that evolved in humid regions tolerate acidic soils better than species like bermudagrass and wheat that evolved in arid and semiarid climates. Wheat farmers also have the option of planting an aluminum-tolerant wheat cultivar and banding phosphorus with the seed at planting, he says.

But eventually, Arnall says farmers and landowners will have to apply lime if their goal is to maintain yields long term. Lime rich in calcium carbonate is needed to raise the soil pH closer to neutral. Lime recommendations from Kansas State University, for example, are designed to bring soil pH up to about 6.7.

“When we lime and raise the pH, that free aluminum combines with hydroxide and carbonates, and it forms minerals that are insoluble or are not very soluble, which are not a problem,” Vocasek adds.

Liming, though, is rarely a cheap fix since the wheat-growing region of the Western Plains is hundreds of miles from lime quarries located in the Midwest. The cost of the lime itself is fairly cheap at the quarry, Vocasek says, but trucking costs can be significant. By the time a lime shipment reaches a farmer’s field, prices can be $20 to $30 per ton, or more. Add in the cost of application and total lime costs can be $75 to $125 per acre depending on the rate of application, with probably a five- to six-year return on investment, Hungerford notes.

The high initial cost and lengthy rate of return, Hungerford says, is the main reason farmers ignore pH problems. However, if applying the full rate of lime is not financially feasible, even applying a half or quarter rate can help yields in the short term to boost pH above 5.5, according to Kansas State University recommendations.

Liming is further complicated if farmers are locked in a short-term lease with a landlord, adds Arnall, making a long-term investment in lime high risk if farmers lose control of the land before extracting full value of the lime.

Mykel Taylor, agricultural economist at Kansas State University, says the landlord commonly pays the cost of the lime since it’s a long-term improvement to their land. But if the cost is shared between the landlord and tenant, full compensation has to be written into the contract if the farmer loses the land.

“We highly encourage them to negotiate with their landlord the terms of the lease such that if it ends before the full value of that investment is depleted, they are compensated for that,” she says. “Having that prorated refund component to it is just good lease negotiating no matter how you have the lease, whether it’s cash or a crop share. It gives the right incentives to everybody.”

Smart on lime

When selecting a lime source, the cost per pound of effective calcium carbonate, or ECC, should be a primary factor in source selection,
agronomists advise. As long as the same amount of ECC is applied, any lime source will do. But with high transportation costs, Hergert recommends seeking out alternative sources of lime like leftover waste from sugar beet processing.

“One thing that we have here in the panhandles and eastern Colorado where we grow sugar beets is a by-product that’s called precipitated calcium carbonate from the sugar-refining process,” Hergert says. “A sugar factory, like here in Scottsbluff, will produce 50,000 tons of precipitated calcium carbonate every year, and they’ve been doing it for 100 years. They’ve been piling it up, and they are worried about what they’re going to do if they have to get rid of it.”

Locally sourced precipitated calcium carbonate, he says, could be cheaper with less freight cost compared with lime from a distant quarry.

Liming a field, meanwhile, can pose challenges to some farmers after application, specifically for farmers in a no-till system, Peterson warns. If lime is not incorporated with tillage, the pH of the soil surface will be higher and will extend herbicide activity.

“Make sure you are aware of the herbicides that are affected by high pH, and look for alternatives that aren’t affected so much,” Peterson recommends. “Or at the very least, just be aware of what crop rotations you can work with. In most cases, we’re talking about herbicides that control broadleaf weeds like atrazine and sulfonylurea products, such as Finess, Ally, and Rave. Herbicide carryover potential to broadleaf crops and corn from sulfonylurea herbicides is much greater with higher soil pH. The main thing is to read those labels.”

Added together, managing acidified soils is a complicated matrix of issues for farmers and landlords who may not fully understand a problem that has crept up on them over time, Vocasek notes.

Vocasek recalls a farmer in south-central Kansas in the early 1980s who continued to see his yields drop year after year. The farmer thought it was a nutrient problem, so he continued adding nitrogen. Even when the field had 200 lb/ac of nitrogen, his wheat barely yielded 20 to 25 bu/ac. Rather than helping the crop, he says, the farmer was just accelerating the acidification process.

With the complicated issues of acidified soils sure to grow across the Plains, Vocasek stresses that CCAs play an even greater role now in advising farmers and landowners on how to properly address pH issues. Without proper knowledge, he says, farmers and landowners may be creating bigger problems for themselves in the future.