It's all a matter of pH

ACIDIC SOILS, ALUMINUM TOXICITY ARE ON THE RISE IN EASTERN WASHINGTON, NORTHERN IDAHO

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Does your wheat stand start a little slow? Are plants stunted? Do they look yellow? Are there places in the field that are thin or even bare?

Potential culprits for these symptoms include the soil-borne diseases Rhizoctonia or Pythium, pests such as nematodes or wireworms, herbicide carryover or even inadequate or skipped fertilization. If, however, you rule out all these factors, it might be time to investigate aluminum toxicity, a menace that is increasing every year in areas of the Pacific Northwest.

Declining soil pH in Eastern Washington and Northern Idaho caused by the annual application of fertilizer needed to grow crops, has thrust aluminum toxicity to the fore as an emerging regional production issue. Prior to farming, soil pH in much of the Palouse was near 7 (neutral), and aluminum was tightly bound to soil particles or organic matter. As the pH begins to decline below 5.5 (more acidic), some of this aluminum becomes freely available to the plant.

As pH declines even more, the free aluminum in the soil increases dramatically. Unfortunately, this free form of aluminum is toxic to plants, interferes with normal growth and results in a poor root system. This reduces the ability of the plant to take up water and nutrients and results in reduced stand and stunted plants that are often pale in color and produce fewer tillers and smaller heads.

The pH of soil is declining because the nitrogen within the fertilizers farmers use undergoes natural chemical reactions in the soil, with the help of beneficial microorganisms that convert ammonia and ammonium forms of nitrogen into nitrate. Unfortunately, during this conversion process, hydrogen ions are released into the soil leading to soil acidification. Low soil pH not only frees up aluminum and leads to toxicity in plants, it also limits the availability of key plant nutrients (nitrogen, phosphorus, magnesium, molybdenum).

While pH has been dropping throughout the region, the acute symptoms of soil acidity and aluminum toxicity have begun to emerge in locations that were historically forested. That's because native soil in forested locations had a lower starting pH than prairie soil when active farming began on these sites. Forested soils also had lower organic matter when initially broken out, making them more vulnerable to shifts in soil pH.

Contrary to what is observed with low pH and increasing free aluminum in formerly forested soils, low pH in prairie soils in Eastern Washington and Northern Idaho do not necessarily have high concentrations of free aluminum. That's because these prairie-derived soils have a high base saturation, thus low exchangeable aluminum. Or to put it more simply: even with soil pH below 5.5 in prairie soils, the quantity of free aluminum is not high enough to cause toxicity to plants. For now, anyway.

So how do we solve this problem? There are several solutions being examined. The most likely management strategies include planting tolerant varieties of wheat, incorporating aluminum-tolerant crops into the rotation and lime applications to mitigate soil acidity. Fortunately, some wheat varieties and emerging breeding lines are tolerant to aluminum-toxicity. These plants have genes that secrete organic acids, such as malate, from their roots to bind with the toxic free aluminum, preventing plants from taking it up.

A preliminary screen of PNW varieties for aluminum tolerance was conducted by Brett Carver, wheat breeder at Oklahoma State University. He discovered we do indeed have resistance in some of our spring and winter wheat varieties.

Following the initial Oklahoma screen, a pilot study was initiated in 2011 at a site in Spokane County documented to have low pH and aluminum toxicity problems. In 2012, Washington State University spring wheat breeder Mike Pumphrey expanded the screening to include 24 varieties of soft white spring wheat and 30 varieties of hard red spring wheat.

Overall, there was good agreement with our initial findings. Based on our most recent data (see table 1), varieties highlighted in blue with a rating of 2 or less would be suitable for growing in fields with known aluminum toxicity issues. All other varieties are sensitive and would be risky to plant in these fields. A winter wheat trial was seeded in the fall of 2012 to gather similar information on winter varieties.

Most crops grown in dryland production areas of Eastern Washington and Northern Idaho are quite sensitive to low pH and aluminum toxicity, including wheat, barley, peas, lentils, canola, mustard and camelina. However, oats and triticale are quite tolerant of these conditions. In side-by-side comparisons in farmer fields, winter triticale regularly outyields moderately tolerant wheat with yields often twice that of the wheat.

The availability of tolerant crops and our growing knowledge about aluminum tolerance within PNW wheat varieties, however, does not address the

It doesn't take a microscope to determine which wheat plant roots were stunted by aluminum toxicity.

Table 1: Varieties suitable for growing in fields with known aluminum toxicity issues

	Variety	Yield (bu/A)	Rating (0 - 5)
Soft White	Babe	40	2
	Whit	40	2
	WB-1035CL+	40	2
	WA 8162	39	2
	IDO687	37	2
	IDO671	36	2
	Nick	36	2
	IDO686	33	2
	Alturas	32	2
	Alpowa	31	2
	JD	12	4
	Zak	11	5
	Wakanz	11	5
	Diva	9	5
	Louise	8	5
	WA 8161	7	5
	IDO599	7	5
Hard Red	WA 8166	45	2
	WA 8165	43	1
	WA 8163	39	2
	Tara 2002	39	1
	IDO694	38	2
	WB Hartline	36	3
	Clear White 515	35	2
	LCS Albany	35	2
	Otis	34	3
	LCS Powerplay	30	2
	Expresso	26	3
	Hank	20	4
	LCS Buck Pronto	18	4
	BR7030	11	4
	Scarlet	10	4
	Glee	10	4
	Jedd	9	5
	Bullseye	8	5
	WB-Fuzion	7	5
	Kelse	7	5
	Jefferson	7	5
	Hollis	6	5
	Lassik	6	5
	SY605 CL	5	5

Varieties suitable for growing in fields with known aluminum toxicity issues in blue, those unsuitable in pink.

underlying problem of low soil pH. The tolerance is quantitative, so as soils become more acidified and the quantity of free aluminum increases, even the yields of tolerant wheat varieties and alternative crops will decrease. A longer term solution to the problem should include some form of lime application, either in-furrow or broadcast and then incorporated into the soil.

For the past two years, studies have been underway in the Rockford area (10 miles south of Spokane) to test the benefit of applying lime to both aluminum-tolerant and sensitive wheat. In order to demonstrate that lime application increases wheat yields, 10 tons of lime an acre (15 tons dolomite per acre) was applied in November 2010. Spring wheat varieties were planted in 2011 and 2012. Each year, the limed plots in combination with an aluminum tolerant variety showed significant yield increases (28 percent to 46 percent). Little effect was seen with the sensitive variety in 2011, although there was a nearly three-fold increase in yield in 2012. Overall, there was a substantially higher yield using an aluminum-tolerant variety over a sensitive variety.

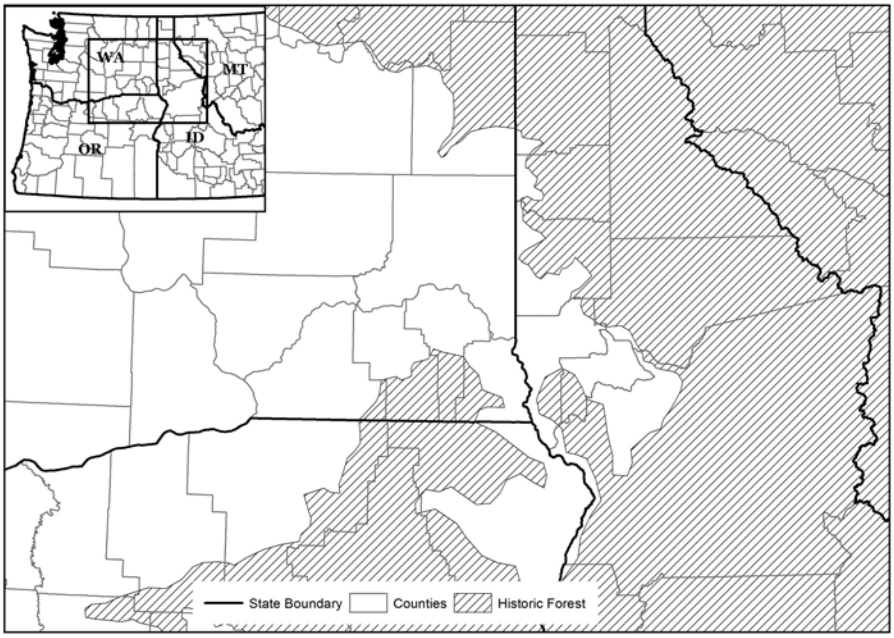
Although the quantity of lime applied in the pilot study is not economically feasible on a large scale, it demonstrates that yields can be boosted by its application. The exact amount of lime needed to achieve optimal increases in pH without busting a farmer's budget is the subject of future research.

As an alternative to broadcast applications of large amounts of lime, a pilot study was initiated in the summer of 2012 examining in-furrow applications of lime. Here, prilled calcium carbonate was added with the seed at planting at a rate of 150 pounds an acre. Several aluminum tolerant and intolerant varieties were included. Although there was not a noticeable

Triticale, which is a cross between wheat and rye, is naturally more tolerant to aluminum toxicity than most wheat varieties. The winter wheat on the left is slightly tolerant.

Washington farmers are lucky the problem with aluminum toxicity is not widespread throughout Eastern Washington. Reclaimed forest soil tends to be hardest hit by the phenomenon which can decimate susceptible varieties as shown in this screening plot.

Not all varieties are created equal when it comes to aluminum toxicity. Louise, a soft white, and Jedd, a hard red, are among the varieties that are extremely sensitive.



Historically forested areas are harder hit by aluminium toxicity issues.

(Above) A hard red variety, like Tara2002, or a soft white variety, like Babe, are naturally resistant to aluminum toxicity. (Below) This is not what you want your soft white spring wheat to look like after tillering, a result of aluminum toxicity.

difference between the treated and nontreated areas within the field, an average gain of 3.3 bushels per acre was observed across all varieties. Looking at the tolerant varieties, Tara 2002 and WA 8166, a gain of 5.7 bushels per acre was attained.

Further evaluations need to be completed to determine optimal rates for the in-furrow application. The quantities used in this study were minimal and will not provide much benefit toward changes in the soil pH, but it could offset the acidification of fertilizer added for that year, and perhaps alter the seed zone during establishment.

The ideal solution for managing soil acidity and associated aluminum toxicity is to plant a tolerant crop or wheat variety and integrate some type of lime application. This will not only provide the greatest improvement in yield, but the addition of lime will improve fertilizer uptake efficiency of the plants and increase the availability of other micro- and macronutrients in the soil. More research is required, however, to determine which method(s) of lime application will result in improved plant health and yield while proving economical.

For farmers who believe soil acidity and aluminum toxicity may be a problem in their fields, the first step is to get a soil test for pH. If the pH is below 5.5 and the field is in a historically forested area, it is possible that aluminum toxicity is a problem. If the pH test includes exchangeable aluminum as a percentage of the cation exchange capacity, verify that it is under 60 percent. Exchangeable aluminum over 60 percent can result in aluminum toxicity.

Aluminum toxicity can be verified in crop by examining the roots for characteristic twisting and short, stubby roots. It is also wise to have a mature plant's tissue tested for aluminum. Concentrations above 200 ppm (mg/kg) indicate aluminum toxicity. ■