Soil Acidity and Aluminum Toxicity in the Palouse Region of the Pacific Northwest

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS050E

In the early 1980s, Dr. Robert Mahler of the University of Idaho published several research articles and Extension bulletins on soil acidification on the Palouse (Mahler et al. 1985; Mahler and McDole 1985; 1987a,b; 1994). At that time, Mahler and other researchers cited recent and archival data that indicated pH in the surface foot of soil had declined from near neutral (7.0), before farming began, to values below 6.0 in up to 65% of the fields surveyed (Mahler et al. 1985). A large number of fields had a soil pH below 5.5 and a few fields were below 5.0. Soil pH has continued to decline throughout the Palouse, and practices such as conservation tillage have led to the development of an intensified layer of acid soil at the depth of fertilizer placement (Figure 1).

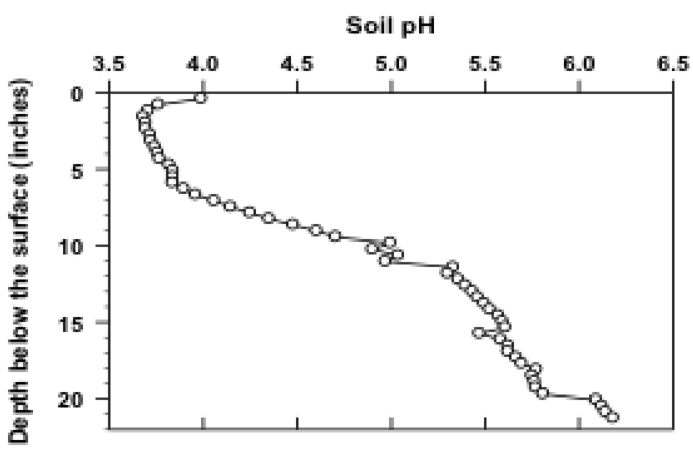

Figure 1. Soil pH (1:1 soil:water ratio) profile from a no-till field near Rockford, WA, Fall 2010 (Koenig et al. unpublished).

Soil acidity has a dramatic impact on most chemical and biological processes. In plants, soil acidity can cause aluminum toxicity that leads to severe yield reductions. In general, legumes are less tolerant of soil acidity than cereals such as wheat and barley. This is because acid soil affects the legume's ability to fix atmospheric nitrogen by reducing populations of Rhizobium bacteria (Mahler and McDole 1985). Mahler and McDole (1987) defined critical soil pH values (1:1 soil:water ratio) in the first surface foot of soil for peas (5.5), lentils (5.6), wheat (5.2 to 5.4), and barley (5.2) in northern Idaho. Below these soil pH values, crop yields declined dramatically. They also showed substantial yield responses to lime applications at sites with soil pH below these critical values (Mahler and McDole 1985).

Recent field trials involving lime applications across a range of Washington Palouse locations showed no response to lime in spring peas, wheat, or barley in fields with a pH as low as 5.0 in the first surface foot of soil (Brown et al. 2008; Koenig unpublished data). These studies were conducted at sites historically covered by grass vegetation. An important feature of these sites is that the soil's base saturation is still relatively high and its exchangeable aluminum is low, even though pH has dropped below critical levels (as established for these crops in the 1980s by Mahler and McDole). Due to higher base saturation and lower aluminum concentration, historical grassland soils are at lower risk of problems with aluminum toxicity. Areas historically covered in forest vegetation (Figure 2) are currently at greater risk of aluminum toxicity, since these areas commonly have lower pH throughout the soil profile depth, lower base saturation, and higher concentrations of exchangeable aluminum. Recent field trials (Paulitz and Schroeder unpublished)

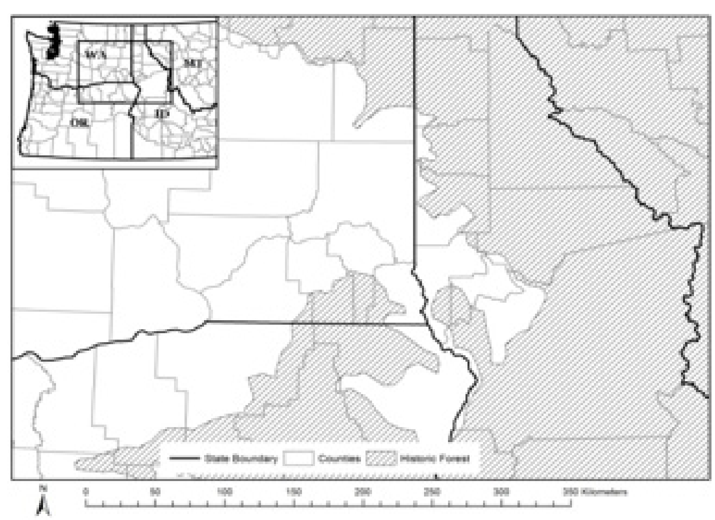

Figure 2. The historic distribution of forests in the inland Pacific Northwest. Shaded areas indicate current or historic forested areas at higher risk for aluminum toxicity when soil pH is below 5.5 (Hessburg et al. 1999).

conducted at a northeast Washington site historically covered by forest vegetation showed dramatic spring wheat responses to lime applications. Also, Dr. Mahler's original liming work was conducted at locations historically covered by forest vegetation.

As farmers and consultants on the Palouse continue to observe declines in soil pH, many are asking what they should do. It would be useful to review the map in Figure 2 to determine if a field is in a historic forested area. If it is not, the current risk of having soil pH affect crop production is low, although soil pH and crop health should continue to be monitored. If the field is in a historic forest area, and if soil pH is below 5.5, further investigation should be carried out by submitting a sample of the top foot of soil to a qualified testing lab (Daniels 2011). Lab tests should provide an analysis of exchangeable aluminum as a percentage of the cation exchange capacity. Values above 60% exchangeable aluminum indicate a potential toxicity problem. Plant testing can confirm toxicity exists if concentrations above 200 ppm (mg/kg) total aluminum are detected in mature tissue. Roots can also be inspected for characteristic symptoms of aluminum toxicity, including deformed roots that are thickened and twisted and have club ends (Figure 3). Other symptoms are root tips and lateral roots that are stubby, have turned brown, and have no fine branching in the root system. Aboveground symptoms will appear as yellowing of the leaves and stunting of the plant's growth, and these symptoms become more apparent as temperatures increase and moisture near the soil surface is depleted.

Figure 3. Symptoms of aluminum toxicity on a susceptible spring wheat variety Scarlet (right) versus healthy roots of the aluminum-tolerant Canadian variety Alikat (left). Photo courtesy of Dr. Kurt Schroeder.

Soil pH is highly variable across the Palouse landscape, and values can range as wide as two full pH units within a field. As a result, soil acidity problems may appear in small patches or large portions of fields, depending on the spatial distribution of low soil pH. Conservation tillage may aggravate pH problems (Figure 1), though the full implications of stratified soil acidity in reduced tillage systems are unknown at this time.

Long term use of ammonium-based fertilizers, coupled with crop rotation and the removal of residue, are responsible for the decline in soil pH on the Palouse

Table 1. Rating of Pacific Northwest winter and spring wheat varieties according to aluminum tolerance. Ratings were performed by Dr. Brett Carver at Oklahoma State University using a numerical 0–5 scale where 0 = tolerant and 5 = sensitive. Ratings are based on visual observations of plant vigor and lack of aluminum toxicity-associated chlorosis in comparison to known aluminum-tolerant check varieties.

Winter Wheat				Spring Wheat			
Variety	Rating	Variety	Rating	Variety	Rating	Variety	Rating
Soft white		*Hard red*		*Soft white*		*Hard red*	
Legion	1	Paladin	2	Alpowa	0	Hank	1
Madsen	1	Whetstone	2	Babe	0	Tara 2002	1
ARS-Amber	2			Nick	0	Buck Pronto	2
Badger	2	*Club*		Whit	0	Kelse	3
Brundage 96	2	Chukar	2	Penawawa	1	Westbred 926	3
Masami	2			Diva	2	WB Fuzion	3
WB-528	2			Louise	3	Jefferson	4
Xerpha	2			Zak	3	Scarlet	4
Finch	3			Wakanz	4	Lassik	5
Legacy	3					Bullseye	5
Tubbs	3			*Hard white*		UI Winchester	5
Eltan	4			Macon	1		
Skiles	5			Otis	1	*Club*	
Stephens	5			BR7030	3	JD	0
						Eden	4

(Mahler et al. 1985). Unfortunately, farmers have few alternative sources for nitrogen fertilizer that are both economical and do not acidify soil. Fortunately, a recent screening of Pacific Northwest winter and spring wheat varieties revealed a range of aluminum tolerances (Table 1). These are preliminary findings based on one year of screening in an acid soil nursery in Oklahoma (Carver, Oklahoma State University, unpublished). A subset of spring wheat varieties was planted in acidic soil at a site near Rockford, WA in 2011. Initial observations revealed that the varieties JD, Babe, and Whit performed well, while Scarlet and Bullseye did not. In light of these findings, tolerant wheat varieties should be selected when planting in historic forest areas that are low in soil pH. In the long term, liming will be required in areas where severe acidity develops (Mahler and McDole 1994).

References

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