WASHINGTON STATE UNIVERSITY EXTENSION

RECOMMENDED CROP SPECIES AND WHEAT VARIETIES FOR ACIDIC SOIL

Soil Acidification Series

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Recommended Crop Species and Wheat Varieties for Acidic Soil

Introduction

As discussed in the Implications for Management – An Introduction, not all crop species—nor all varieties within species—respond the same to acidic soil (Figure 1). Of the crops commonly grown in eastern Washington and northern Idaho, legumes are the most sensitive to soil acidity, while wheat and barley are less sensitive, followed by triticale and grass hay/seed crops, which can tolerate more acidic soil (Table 1). Canola and buckwheat also fare better on acidic soils than legumes and some wheat varieties, although canola is relatively sensitive to manganese (Mn) toxicity, which can be a problem on some acidic soils.

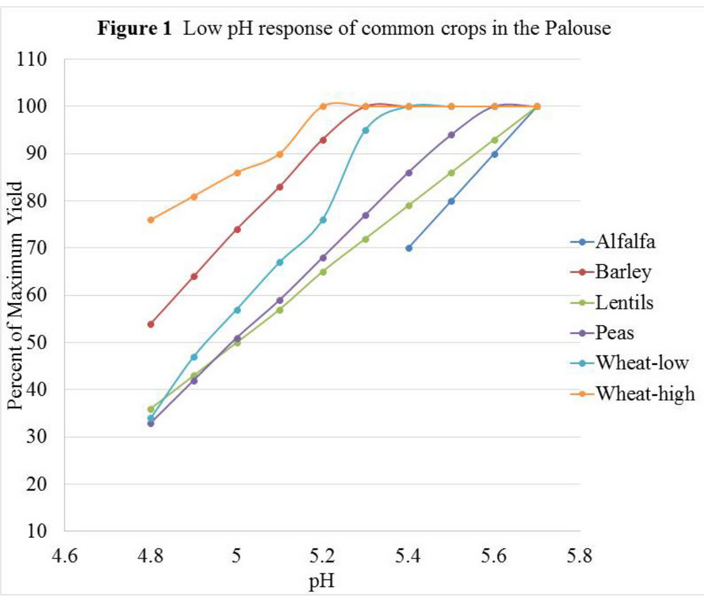

Figure 1. Yield response of common crops to declining soil pH in the Palouse (adapted from Mahler and McDole 1987). Wheat is differentiated here by its level of genetic tolerance: "wheat-low" values indicate results for varieties with low tolerance to acidity and Al. The "wheat-high" values indicate results for varieties with higher tolerance to acidity and Al.

The response of a particular crop to acidic soil will also depend on soil characteristics other than pH, such as soil fertility, microbiology, organic matter content, concentration of available aluminum (Al), etc., so it is difficult to prescribe an absolute pH cutoff value under which a certain crop or variety will begin to lose productivity, and at what pH point yield loss will become economically prohibitive. Furthermore, productivity does not decline at the same rate for each crop, as seen when comparing alfalfa to a highly tolerant wheat variety (Figure 1), so it may be economically feasible, for example, to produce tolerant wheat at a pH farther below its critical value than alfalfa could withstand.

Table 1. Critical pH below which crop species lose significant productivity

	Crop	Critical pH
Legumes		
	Alfalfa[a]	6.0
	Chickpea	Unknown
	Lentil[b]	5.7
	Pea (spring)[b]	5.5
Grasses		
	Barley (spring)[b]	5.2
	Kentucky Bluegrass (seed)	Unknown
	Timothy (hay)[c]	5.5
	Triticale	Unknown
	Wheat[b]	5.2-5.4
Alternative crops		
	Canola[d]	5.5
	Buckwheat[e]	5.4

[a](Koenig et al., 2009)
[b](Mahler and McDole 1987)
[c](Ogle et al., 2011)
[d](Brown et al., 2009)
[e](Björkman 2009)

Fine-tuned crop and variety selection decisions will therefore depend on the individual experiences of growers in their unique environments.

The following guidelines should help in the process of crop and varietal selection when farming on acidic soil, and the use of superior varieties in conjunction with other important acidity-mitigating tools in the grower's integrated toolbox should ultimately improve farm productivity.

Relative sensitivity of common regional crops

Of the legumes (alfalfa, chickpeas, lentils, and peas), alfalfa is, in general, the most acid-sensitive, followed in order of decreasing sensitivity by lentils, peas, and chickpeas, as shown in Table 1 (Mahler and McDole 1987; Koenig et al., 2009). Legume yield on acid soil is largely impacted by the reduced ability of symbiotic rhizobia to perform in low-pH conditions. It has been observed that the rhizobial species that colonize chickpea nodules are more vigorous at low pH than those colonizing peas, lentils, and alfalfa. This explains the superior performance of chickpeas over other common legumes on acidic soil.

It should be noted that, although nitrogen fixation by legumes tends to slowly acidify soil, the acidification caused by fertilizing non-leguminous crops with ammonia-based fertilizers can be much more rapid (depending on the quantity and quality of fertilizer supplied).

The regionally dominant cool-season crops of wheat and barley are more tolerant of acidity than are legumes, but yields of even relatively tolerant options will still be compromised by many of the low-pH soils in eastern Washington and northern Idaho. More tolerant crops also include triticale, timothy, Kentucky bluegrass, and buckwheat.

Mechanisms of tolerance

The main growth-limiting factor in acidic soil is aluminum (Al) toxicity. As pH falls below neutral, Al is increasingly released from natural soil minerals into the plant-available soil solution.

Immediately following seed germination, cell walls in emerging root tips are bound by Al in acidic soil solutions and become prematurely stiff and brittle, resulting in root stunting (Figure 2) (Ma et al., 2004).

Figure 2. Seedling root growth of some tolerant and sensitive wheat varieties, with and without aluminum (Al) exposure, in a hydroponic solution. Note the root stunting of the sensitive variety Eltan, compared to the healthy root growth of the more tolerant variety Babe. Photo credit: P. Froese.

Stunted roots access less water and mineral nutrition than healthy roots, and, as a result, support less crop growth and yield throughout the growing season.

As mentioned above, however, some crops are more tolerant of acidity and Al than others, and even between varieties within each of the crop species there can be wide ranges in tolerance. What makes the difference?

Research into Al tolerance has shown that many tolerant plant varieties protect their roots from contacting Al in the soil solution by producing compounds such as citrate or malate and pumping these into the area of soil immediately contacting the root, called the rhizosphere. These plant-produced defense compounds chelate (chemically bind to) Al, keeping it from binding to root cells, thereby allowing root growth to proceed normally for roots thus protected from Al contact. A plant variety's tolerance level therefore depends on how much citrate, malate, or both it is able to exude into the rhizosphere. Of course, this defense mechanism does not provide complete immunity and even relatively tolerant varieties will grow and yield better where soil acidity and free Al concentrations are less severe.

There are likely many other less impactful, yet still important, mechanisms of Al tolerance at work in cultivated crops, such as rapid root growth through acidified soil strata, internal Al detoxification, and improved phosphorous (P) use efficiency. (P is bound by Al and is usually highly unavailable in acidic soils.)

Tolerant wheat varieties

Of all the crops grown in eastern Washington and northern Idaho, wheat is the most diverse in terms of the number of available varieties and the dramatic differences between varieties in response to soil acidity. In 2014 more than 60 different varieties of spring and winter wheat were cultivated in Washington alone (Washington Grain Commission, 2014).

Looking toward the future, winter and spring wheat breeding programs at Washington State University are actively breeding for improved acidity tolerance in new cultivars. However, in the course of testing current varieties and breeding lines on acidic soil to identify parents with genetic tolerance, some currently available cultivars with superior low-pH performance have been identified. Variety testing results are reported in Table 2, which lists varieties that have shown the best tolerance of all lines tested. These results are not absolute, and testing continues.

Table 2. Wheat varieties with moderate acidity tolerance[a]

Spring Wheat	Winter Wheat
Hard red spring SY Steelhead Solano Tara 2002 Chet (WA 8165) WB9879CLP Alum (WA 8166)	**Hard red winter** Whetstone Eddy Norwest 553 Finley Boundary Paladin
Hard white spring LCS-Atomo Otis UI-Platinum (IDO694C) WB Hartline	**Hard white winter** MDM
Soft spring Whit Babe WB-1035CL+ Nick Alpowa Alturas WB6341 Seahawk (WA 8162)	**Soft winter club** Coda Cara[b] Tres Chukar[b] Moro Crescent[b]
	Soft winter common WB 528 ARS Amber ARS Selbu Tubbs Weatherford Brundage 96 ORCF-102 Hubbard AP Legacy Xerpha[b] Simon Mary Masami Finch[b] Brundage CF

[a]Evaluated on acidic soil in Freeman and Rockford, WA.
[b]Moderately resistant to Cephalosporium stripe disease.

Tolerance rating in the field can be tricky due to the high level of spatial variation in pH and available Al even within the same test plot, making absolute comparisons between tolerance results from different years or locations difficult. The varieties listed in Table 2 have been observed to perform better than most when grown in low pH and high free-Al soil conditions. Researchers expect that, by breeding and selecting for tolerance, new varieties will be produced that will outperform the most tolerant spring and winter wheat options currently available. This table will be routinely updated as annual testing continues and new varieties are developed.

Varieties listed here are the most appropriate for acidic land, though fields with severe acidity and Al toxicity may not be suitable for wheat production at all, and a different crop such as triticale or timothy may be a more reasonable choice until pH can be raised with lime.

Keep in mind that low pH enhances the severity of Cephalosporium stripe disease of wheat, so if this disease is in your soil, winter wheat varieties with genetic resistance to it should be preferred.

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