Effect of Soil pH on Wheat Diseases

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December 14, 2017

Learning objectives:
What is soil pH?
Why do we care?
How does it affect crop diseases?

What is pH?
- a measure of hydrogen ion (H⁺) concentration (activity) of a solution
- concept developed in 1909 by a Danish scientist:
  \[ \text{pH} = -\log [H^+] \]

For water:
\[ \text{H}_2\text{O} = 2\text{H}^+ + \text{OH}^- \]
\[ H^+ = 0.0000001 \text{ M (1 x 10}^{-7} \text{ M)} \]
\[ \text{pH} = -\log [1 \times 10^{-7}] = -(-7.00) = 7.0 \]
Acidic solutions have more H⁺ ions
Basic solutions have more OH⁻ ions

Why do We Care?
pH of agricultural soils in the PNW is decreasing
< pH 6.6 is considered acidified for ag soils
alarmingly low in some areas (< pH 4.0)

A Growing Issue - Soil Acidification

Columbia County, 2013

Soil pH at four depths at 76 sites surveyed across Columbia County

Mahler et al., 1985

Ranges from 0 to 14
- Difference between units = 10X

Acidic solutions have more H⁺ ions
Basic solutions have more OH⁻ ions

Why do We Care?
pH of agricultural soils in the PNW is decreasing
< pH 6.6 is considered acidified for ag soils
- alarmingly low in some areas (< pH 4.0)
Soil Acidification?

Why?
- Application of ammonium-based \([\text{NH}_4^+]\) nitrogen fertilizers

Soil acidity # for # of product:
Anhydrous > Am. Sulfate > Urea > Am. nitrate

Why do We Care?
- In soil, ammonium is converted to nitrate \([\text{NO}_3^-]\) by microbes in a two-step process known as nitrification:
  \[
  2 \text{NH}_4^+ + 3 \text{O}_2 \rightarrow 2 \text{NO}_2^- + 2 \text{H}_2\text{O} + 4 \text{H}^+
  \]
  \[
  2 \text{NO}_2^- + \text{O}_2 \rightarrow 2 \text{NO}_3^-.
  \]

For every # of \text{NH}_4^+ added, 1.9 to 3.6# lime is required to neutralize the acidity

Impact of Soil pH on Crop Productivity

Mahler 1987: Soil pH vs. Max yield
- 7 studies with Dawes, Hill 81, & Stephens
  - initial pH 5.0-5.3: 0, 1,000, 2,000, 3,000, & 4,000 lbs Lime or Sulfur

Impact of Soil pH on Crop Productivity

Froese et al. 2015

Reasons for Reduced Productivity

- Direct toxicity from Al, Mn, & Fe ions
- Lack of cationic nutrients: Ca, K, Mg
- Low P availability (Fe- and Al-phosphates)
- Altered soil microbiome: *e.g.* toxicity to *Rhizobia* in legumes
- Impact on plant diseases?
**Nutrient Availability**

![Nutrient Availability Chart](image)

- Nitrogen
- Phosphorus
- Potassium
- Calcium & Magnesium
- Sulfur
- Iron and Zinc
- Manganese and (Aluminum)
- Copper
- Zinc
- Boron
- Molybdenum

pH 5.5

*Courtesy P. Carter*

**Impact on Soil Microbiome**

Well-nodulated plants (L) compared with poorly nodulated plants grown in acidic soil (R)

**Measuring Soil pH**

- Extech PH100 Waterproof ExStik pH Meter

**Recommended pH Meter**

<table>
<thead>
<tr>
<th>Source</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>Tequipment.net</td>
<td>$71.99</td>
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<tr>
<td>Amazon.com</td>
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<tr>
<td>Spectrum Technologies</td>
<td>$159.00**</td>
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**Plant Disease**

A harmful alteration of the normal biological development of a plant that results in harmful morphological and/or physiological changes (symptoms)

- **Biotic** = living causes; spread from plant to plant
- **Abiotic** = non-living causes; don’t spread from plant to plant

Are nutrient deficiencies/toxicities diseases?

**Disease Triangle**

Environment

Temperature

Moisture

Soil pH

Virulence

Pathogenic specialization

Inoculum potential

Resistance

Susceptibility
### Fungal Diseases of Wheat in the PNW

<table>
<thead>
<tr>
<th>Common name</th>
<th>Pathogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripe rust</td>
<td><em>Puccinia striiformis</em></td>
</tr>
<tr>
<td>Eyespot</td>
<td><em>Oculimacula yallundae, O. acuformis</em></td>
</tr>
<tr>
<td>Eyespot</td>
<td><em>Cephalosporium gramineum</em></td>
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<tr>
<td>Rhizoctonia root rot</td>
<td><em>Rhizoctonia solani, R. oryzae</em></td>
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<tr>
<td>Fusarium foot rot</td>
<td><em>Fusarium culmorum, F. pseudograminearum</em></td>
</tr>
<tr>
<td>Pythium seed/root rot</td>
<td><em>Pythium spp.</em></td>
</tr>
<tr>
<td>Snow molds</td>
<td><em>Typhula ishikariensis, Microdochium nivalis</em></td>
</tr>
<tr>
<td>Take-all</td>
<td><em>Gaeumannomyces graminis</em></td>
</tr>
<tr>
<td>Soilborne wheat mosaic</td>
<td><em>Wheat soilborne mosaic virus</em></td>
</tr>
</tbody>
</table>

**Fusarium Crown Rot**

![Image of Fusarium Crown Rot](image1)

**Influence of Soil pH on Fusarium Crown Rot**

Smiley et al., 1996:
- Long-term plots at Pendleton; pH changes due to N fertilization
- Soil pH inversely proportional to rate of applied N, organic N & C
- Disease inversely proportional to soil pH

**F. CULMORUM DISEASE RATING (0-8)**

![Graph of F. CULMORUM DISEASE RATING (0-8)](image2)

**Rhizoctonia Root Rot**

- Decay of root cortex and “spear-tipping”
- Bare patches and erratic stands
R. ORYZAE DISEASE RATING (0-8)

![Graph showing disease rating and soil pH relationship]

**Pythium Root Rot**
- Loss of root hairs and fine rootlets, discolored roots
- Reduced and erratic stands

**Pythium Root Rot - Embryo infection**
- pH adjusted with lime and H$_2$SO$_4$
- Embryo infection was measured 48 hrs after planting seed
- Treatment with antibiotic resulted in greater infection at higher pH
  - Microbial involvement

**Pythium Seed Decay - Chickpea**
- Colton, WA
- 23 May 2014

**Isolation and characterization of Pythium isolates**

<table>
<thead>
<tr>
<th>Location</th>
<th>Total</th>
<th>Brown +</th>
<th>Total</th>
<th>Brown +</th>
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</thead>
<tbody>
<tr>
<td>Colton</td>
<td></td>
<td></td>
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<tr>
<td>Larkin</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pedigo</td>
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**Eyespot or Strawbreaker Foot Rot**

![Image of eyespot disease on plant]

*Courtesy K. Schroeder*

*Fukui et al. 1994*

*Courtesy H. Tao & W. Chen*
Influence of Soil pH on Eyespot

Smiley et al., 1996: Incidence of eyespot inversely proportional to soil pH from 4.6–5.2
- only report in the literature
- no data provided ➔ size of response not known

Take-All

Influence of Soil pH on Take-all

Smiley & Cook, 1973:
- Disease severity is related to soil pH and form of nitrogen
- Disease increases with increasing pH
- Ammonium (NH$_{4}^+$)-N resulted in less disease than nitrate (NO$_{3}^-$)
  ➔ acidification of the rhizosphere

Cephalosporium stripe

Influence of Soil pH on Cephalosporium Stripe

WA 1964:
- antibiotic production by C. gramineum
WA 1968:
- survival of C. gramineum enhanced at low soil pH
KS 1985:
- low soil pH favors disease development
Effect of Soil pH on Cephalosporium Stripe and Take-all

Soil pH after Amendment with Lime or H₂SO₄

Influence of Soil pH on Cephalosporium Stripe

Confirmed pH response in Washington

Soil pH after Amendment with Lime or H₂SO₄

Confirm the effect of soil pH on Cephalosporium stripe under PNW field conditions
- Adjust soil pH by adding acid or lime

Influence of Soil pH on Cephalosporium Stripe

Mean of 3 cultivars (Brevor, Nugaines, Daws) in 1987 and 2 cultivars (Daws, Stephens) in 1989

Influence of Soil pH on Cephalosporium Stripe

Soil pH
- soil microbiome
- nutrient availability
- soil structure

Wheat plant
- predisposition
- root exudation

C. gramineum
- inoculum potential
- survival
Influence of Soil pH on Cephalosporium Stripe

Objectives:
- Determine the effect of pH on components of inoculum potential
  - growth, sporulation, and survival and germination of conidia
- Determine the relationship between inoculum density and disease incidence
Effect of soil pH on Cephalosporium Stripe

Growth and sporulation are greater at pH 4.5 than 7.5
- More spores (inoculum) are produced at lower pH
- Fewer spores are needed to cause the same amount of disease at lower pH
- Pathogen survival in straw is greater at lower pH

Root infection seems to be greater at lower pH

Severe Aluminum Toxicity
Spring wheat – Rockford 23 June 2009

ALUMINUM TOXICITY

ALUMINUM TOXICITY

ROOT DAMAGE - ALUMINUM TOXICITY

Effect of Aluminum on Wheat Roots

Four-day-old wheat root tips grown in 5 μM AlCl₃

Seedling root tips of Al tolerant and sensitive lines grown without or with 50 mM Al and stained with hematoxylin to show Al accumulation.

Delhaize and Ryan 1995
Managing Aluminum Toxicity

- Liming soil to raise pH
- Breeding for tolerance

Wheat Varieties for Acid Soils

Spring Wheat:

Winter Wheat:
AP Legacy, ARS Amber, ARS Selbu, Boundary, Brundage CF, Brundage 96, Cara, Chukar, Coda, Crescent, Eddy, Finch, Finley, Hubbard, Mary, Masami, MDM, Moro, Norwest 553, ORCF-102, Paladin, Simon, Tres, Tubbs, WB 528, Weatherford, Whetstone, Xerpha

Hard red, Hard white, Club, Soft white
Resources

- Soil Acidity and Aluminum Toxicity in the Palouse Region of the Pacific Northwest
- Recommended Crop Species and Wheat Varieties for Acidic Soil

Acknowledgements

Paul Carter, WSU Columbia County Extension
Steve Van Vleet, WSU Whitman County Extension
Haiying Tao, WSU Extension Soil Scientist
Kurt Schroeder, University of Idaho

Questions?