1. Effect of flooded and water-logged soils on corn growth and yield

Continued heavy rains are subjecting much of the corn that has been planted to saturated soils or flooding. Early-season flooding can cause immediate problems for small corn plants and can have season-long implications as well.

Saturated soils inhibit root growth, leaf area expansion, and photosynthesis because of the lack of oxygen and cooler soil temperatures. Yellow leaves indicate a slowing of photosynthesis and plant growth. Leaves and sheaths may turn purple from accumulation of sugars if photosynthesis continues but growth is slowed. Corn plants can recover with minimal impact on yield if the plants stay alive and conditions return to normal fairly quickly. Although root growth can compensate to some extent later in the season, a saturated profile early in the season can confine the root system to the top several inches of soil, setting up problems later in the season if the root system is inadequate to extract needed water from lower in the profile.

Young corn plants can tolerate only a few days of full submersion. Before V6, when the growing point is at or below the soil surface, corn can survive only 2-4 days of flooding. Once the water recedes, examination of the growing point may be necessary to determine if plants are still viable. A healthy growing point should be white or cream colored. If the growing point turns grey or brown and begins to soften, the plant likely will not survive. Chances of plant survival increase dramatically if the growing point is not completely submerged or if it is submerged for less than 48 hours. Research has demonstrated yield reductions from early-season flooding ranging from 5% to 32% depending on soil nitrogen status and duration of flooding.

Temperatures can influence the extent of damage from flooding or saturated soils. Cool, cloudy weather limits damage from flooding because growth is slowed and because cool
water contains more oxygen than does warm water. Warm temperatures, on the other hand, can increase the chances of damage.

Saturated soils can cause loss of nitrogen fertilizer by either denitrification (loss of nitrogen to the atmosphere) or leaching (movement of nitrogen beyond the rooting zone). Corn may respond to in-season nitrogen applications if a large portion of early-applied nitrogen is lost to these processes. See the article below for more details about nitrogen losses.

Figure 1. A field of flooded corn in Clay County, taken during the week of June 2-6, 2008 by Linda Sleichter, K-State Research and Extension.

-- Kraig Roozeboom, Crop Production and Cropping Systems Specialist kraig@ksu.edu

2. Nitrogen loss potential in wet soils

With the continued wet weather in many parts of eastern and central Kansas the past several weeks, we now are faced with the potential for leaching or denitrification loss of valuable nitrogen from fields planted or intended for corn and sorghum. N loss processes were discussed in a recent e-Update (No. 134; April 11, 2008) concerning wheat, when
temperatures were very cool. With warm temperatures now, the potential for loss is much greater. As a review, the principles of N loss under wet conditions will be discussed again, particularly as it relates to corn and sorghum.

The leaching and denitrification processes are quite different, and normally occur on different types of soils and under different situations. But both involve the nitrate form of nitrogen. The nitrate-N present in fertilizers such as ammonium nitrate (50% nitrate) or UAN solution (25% nitrate), is immediately susceptible to leaching or denitrification loss. Other forms of nitrogen have to be converted in the soil to nitrate-N before leaching or denitrification would become a problem. This microbial conversion process is called nitrification.

**Factors Affecting Nitrification**

How quickly ammonium-N in soil converts to nitrate-N is a function of soil oxygen content, soil temperature, pH, how the N is applied, and some characteristics of the fertilizer. Nitrification is an aerobic process and requires high levels of soil oxygen. Conditions that reduce oxygen supplies, such as wet soils, will inhibit nitrification and keep N in the ammonium form. Optimum soil temperatures for nitrification are in the range of 75-80 degrees. When urea or UAN are broadcast, nitrification will occur more rapidly than when those materials are banded. The nitrification rate of anhydrous ammonia is even slower, due to the impact of the ammonia on the organisms in the application band. The use of a nitrification inhibitor, especially with banded ammonia, will slow the process of nitrification even further.

**Leaching**

Leaching involves the movement of nitrate-N below the root zone with water. Leaching losses are primarily a concern on coarse-textured, sandy soils, where water moves quickly through the soil profile. Ammonium-N is not readily lost to leaching, even on coarse-textured soils. Ammonium-N has a positive charge, and is retained on the cation exchange capacity (CEC) sites of soils, while nitrate-N has a negative charge and is repelled by the soil and remains in the soil water.

**Denitrification**

Denitrification is the conversion of nitrate-N to gaseous N by soil microbes in anaerobic (low-oxygen, waterlogged) soils. Denitrification loss is a problem normally associated with medium- to fine-textured soils under wet weather conditions. There are several conditions that must be met for denitrification to occur. These include:

* Lack of soil oxygen. The specific soil microbes responsible for denitrification only function under anaerobic soil conditions. Poorly drained, compacted, and/or waterlogged soils have the highest potential for denitrification loss. Poorly drained soils in central and eastern Kansas, and the claypan soils of southeast Kansas, are normally the soils in the
state with the most significant potential for denitrification. Well-drained soils normally pose little risk of significant denitrification loss.

* Nitrate-nitrogen. Denitrification only affects nitrate-N; it has no impact on ammonium-N. Maintaining N in an ammonium form is an effective strategy to avoid denitrification losses, and is the reason there are differences among N sources in denitrification potential.

* Warm soil temperatures with organic residue and/or organic matter. Denitrification is a microbial process, and ample food (organic materials) and warm soil temperatures are required for microbial activity. Like nitrification, the optimum temperatures for denitrification are in the 75-80 degree range.

Table 1. Effect Of Soil Temperature and Duration Of Waterlogged Soil Conditions
C. Shapiro, University of Nebraska

<table>
<thead>
<tr>
<th>Length Of Saturation (days)</th>
<th>Soil Temperature (degrees F)</th>
<th>Nitrate-N Loss (% of nitrate present)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>55 - 60</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>55 - 60</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>75 - 80</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>75 - 80</td>
<td>75</td>
</tr>
<tr>
<td>7</td>
<td>75 - 80</td>
<td>85</td>
</tr>
<tr>
<td>9</td>
<td>75 - 80</td>
<td>95</td>
</tr>
</tbody>
</table>

Table 1 presents some University of Nebraska data reported by Charles Shapiro regarding the potential for denitrification N loss at several soil temperatures and provides some general guidelines for potential N loss. Loss was minimal with soil temperatures of 55-60 degrees F, but severe at soil temperatures of 75-80 degrees. Note that this data represents the amount of nitrate-N potentially lost via denitrification – not necessarily the portion of total N applied. That portion of soil N in the form of ammonium-N is not subject to denitrification.

Summary

So what does all this mean for us now? We have had enough warm, dry days through late April and May that much of the N which was applied early, especially the fall applied N, has likely nitrified. The data above would suggest that where heavy rainfall in late May or early June resulted in several days of saturation, some serious denitrification loss likely has occurred. Will all of the N have been lost? No, but producers who applied all of the N in the fall should be in position to apply an additional 40 to 60 pounds of N if needed.
All corn that appears yellow at this time won't be seriously N deficient. In fields where N application was delayed until late April or early May, especially where ammonia was applied, the majority of the N is likely still present and the corn is likely yellow due to wet feet, and will green up when things dry out and oxygen gets back into the soil. No additional N may be needed.

Trying to sort out exactly how much N loss has occurred in a specific field is difficult, if not impossible. One thing producers can do is to establish some reference strips in the field to serve as a base for comparison. Apply the equivalent of an additional 50 to 75 pounds of N per acre to 3 to 5 areas in a field. (Note: If your crop is in 30-inch rows, then applying 1.8 pounds of urea to 6 rows in a 40-foot-long section = 60 lbs N/acre.) These areas can serve as a point of reference for evaluating your crop.

If you have access to a chlorophyll meter or active crop sensor, you can use these instruments to make measurements of greeneness and growth, and make some fairly good estimates of the amount of N needed. But, even without these tools, the reference strips can help you visually evaluate whether the crop will respond to additional N. At the very least, it will allow you to make an “educated guess.”

-- Dave Mengel, Soil Fertility Specialist
dmengel@ksu.edu

3. Saturated and flooded soybean fields

Ongoing rainfall has caused surface flooding and waterlogged soils in many parts of eastern and central Kansas. About half the soybean crop in those areas has emerged and is in the early vegetative stages (based on the June 9 “Crop Weather” report from Kansas Agricultural Statistics). How will soybean respond to the wet conditions?

In some situations, flooding has caused complete submergence of the entire plant. This may or may not cause damage. If soybean plants are submerged for less than 48 hours, there is a good chance they will survive. Plants can survive under water longer under cool than warm temperatures. Submerged soybean plants can survive for up to 7 days when temperatures are less than 80°.

To find out whether the soybeans are damaged after the water recedes, split the stem at the tip and examine the growing point. A healthy growing point will be firm and white or cream colored. A soft, dark growing point indicates injury. In some cases, the silt coating the plant after short-term flooding can cause more injury and plant death than the water itself.
Flooding and submergence isn’t the only potential problem. Waterlogged soils can also cause problems. When soils are saturated for a prolonged period of time, a lack of oxygen in the roots can lead to the accumulation of lactic acid and other products of anaerobic respiration. This is the underlying cause of damage to plants in waterlogged soils where only the roots are flooded.

Injury can depend on variety, growth stage, duration of waterlogging, soil texture, fertility levels, and diseases present. Interactions of these factors make it hard to predict how a given soybean field will react to waterlogged soils.

Variety differences have been reported and researchers have identified possible genes associated with tolerance to waterlogged conditions. Scientists in Missouri have screened a number of soybean varieties, subjecting them to two periods of flooding, each two weeks in duration. The average yield reduction for all varieties was 61%. Yields were reduced by 39% for the most tolerant varieties and 77% for the least tolerant. Producers should check with their seed supplier regarding information about a particular variety. In Kansas, yield potential and resistance to diseases and insects play a greater role in variety selection than tolerance to waterlogged soils.

Research examining the influence of growth stage on the degree of injury from waterlogged soils has provided mixed results.

* Germination. Saturated conditions during germination can reduce successful germination by up to 40% and can inhibit seedling growth. Seeds that are further in the germination process at the time of saturation sustain more injury.

* Vegetative growth stages. Excess water during vegetative stages usually causes less injury than waterlogging during the reproductive and grain filling stages. Short-term waterlogging (2 to 3 days) at V2 to V4 can cause yield reductions of 0% to 50%, depending on soil texture, variety, and subsequent weather. Yield reductions from waterlogging during the early vegetative stages have been attributed to reduced plant population and shorter plants with reduced branching and fewer pods per plant.

* Waterlogging for 2 to 3 days at R2 usually causes greater yield reductions than if it occurs during the vegetative stages. Waterlogging at R1 reduced the number of pods per node. At R5, yield reductions have been attributed to reduced seed size.

The longer the soil is saturated, the greater the injury, mortality, and consequent yield reductions. During germination, saturated conditions for 48 hours can decrease germination by 30% to 70% depending on the timing of the saturation, nearly twice the yield decrease resulting from durations of 24 hours or less. For plants that have emerged, a waterlogged condition that lasts for less than two days often causes little or no noticeable yield reduction. Intolerant varieties begin to show yield reductions after 2 days of saturation, but tolerant varieties can withstand up to 4 days of waterlogging with little reduction in yield. As the duration of soil saturation increases, researchers have
documented greater reductions in population, height, pods per plant, yield, and leaf tissue nitrogen.

Nitrogen-fixing *Bradyrhizobia* species need oxygen to survive in the soil, so flooding can potentially affect their abundance in the soil. *Bradyrhizobia* invade soybean roots and form nodules within the first few weeks of soybean growth. The first nodules appear about one week after emergence and can supply most of the plant’s nitrogen requirement 10 to 14 days later. Nodules are active for six to seven weeks. New nodules continue to form until pod fill when energy allocation to the grain has priority over the energy-demanding nodules.

Saturated conditions for less than 7 days likely will not impact *rhizobia* populations. If saturation persists for 7 to 10 days or longer, populations may decrease, potentially delaying or decreasing nodulation or causing uneven nodulation throughout the field.

Soil conditions play a role in the severity of injury from waterlogging as well. Coarser textured soils will drain more quickly, minimizing the duration of oxygen deprivation to the roots. Fine textured soils maintain saturation longer, increasing the chances of injury.

Higher levels of soil nitrates can minimize injury from flooding, but fertilizing after the soil has dried is generally not helpful. Most Kansas soils mineralize enough nitrogen during the season to maintain the young soybean plants until nitrogen fixation becomes well established. Fertilizer nitrogen will inhibit nodule formation and nitrogen fixation.

-- Kraig Roozeboom, Crop Production and Cropping Systems Specialist  
kraig@ksu.edu

-- Chuck Rice, Soil Microbiology  
cwrice@ksu.edu

These e-Updates are a regular weekly item from K-State Extension Agronomy and Steve Watson, Agronomy e-Update Editor. All of the Research and Extension faculty in Agronomy will be involved as sources from time to time. If you have any questions or suggestions for topics you'd like to have us address in this weekly update, contact Steve Watson, 785-532-7105 swatson@ksu.edu, or Jim Shroyer, Research and Extension Crop Production Specialist and State Extension Agronomy Leader 785-532-0397 jshroyer@ksu.edu