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G1904

Plant Growth and Yield as Affected by Wet Soil Conditions Due to Flooding or Over-Irrigation

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Wet soil conditions caused by flooding or over-irrigation can damage crops, reduce yields, and contribute to groundwater contamination. Adopting proper irrigation management strategies can limit negative impacts.

Proper irrigation management is required to maintain adequate soil moisture in the crop root zone for healthy plant growth and optimum yield. This publication provides information on the potentially negative impacts excess water or wet soil can have on crop growth and yield, soil oxygen, and the carbon dioxide concentration balance.

The impact of excess water on crop growth and yield is influenced by crop type, soil characteristics, duration of excess water or flooding, initial soil water and nitrogen status of the soil before flooding, crop stage, soil and air temperature, and other factors.

In the past few years, water resources have become increasingly stressed in many agricultural areas in Midwestern states due to a combination of drought and over-pumping surface and groundwater. Increasing demand for biofuel production has resulted in some shifts from a traditional corn-soybean rotation to continuous corn production. Shifts from dryland to irrigated agriculture also stress available water resources. In fact, large portions of the Ogallala aquifer, which extends from Texas to South Dakota and Wyoming, already show water table declines of more than 100 feet. Thus, growers in the region are under increasing pressure to use water resources as efficiently as possible.

Adopting proper irrigation management strategies can reduce the negative impacts of over-irrigation and provide a balance between the crop water requirements and available water. Over-irrigation leads to water loss, increases energy use for pumping, causes leaching of nitrogen and other micronutrients, and wastes time. Crop nitrogen needs, fertilizer costs, and nitrogen losses to groundwater also result from over-irrigation. Improper irrigation and fertilization management can be a major contributor to groundwater contamination.

The objective of irrigation management is to establish proper timing and amount of irrigation for greatest effectiveness. This will minimize yield loss due to crop water stress, maximize yield response to other management practices, and optimize yield per unit of water applied. All of these factors contribute to farm profitability. Poor irrigation management that results in either excessive or inadequate water application can significantly reduce the potential for profitability. Proper irrigation management also helps reduce the potential for runoff and reduce soil erosion and pesticide movement into surface and groundwater.

The following University of Nebraska–Lincoln Extension publications provide practical information about managing irrigation for row crops: *Irrigating Soybean* (G1367), *Irrigating for Maximum Economic Return with Limited Water* (G1422), *Irrigation Management and Crop Characteristics of Alfalfa* (G1778), *Irrigation Management for Corn* (G1850), *Firming Irrigation Furrows to Improve Irrigation Performance* (G1720), *Managing Furrow Irrigation Systems* (G1338), *Predicting the Last Irrigation of the Season* (G1871), *Using Modified Atmometers (ET_{gage}) for Irrigation Management* (G1579), and *Watermark Granular Matrix Sensor to Measure Soil Matric Potential for Irrigation Management* (EC783).

Over-irrigation

Over-irrigation results in nitrogen leaching and runoff. Research has shown that excess water can increase weed pressure and create an environment favorable to diseases. Crop growth and yield can also be impeded when over-irrigation:

- disturbs the oxygen balance of the root zone, drowns roots, reduces plant water uptake, and thus stresses plants.

- reduces the exchange of air (oxygen) between the soil and atmosphere, and causes reductions in root growth (especially in the upper soil layers) and less transport of water and nutrients through the roots to the upper parts of the plant.
- increases microbial growth which can cause the formation of sulfides and butyric acid that are toxic to plants.
- increases the potential for root diseases.
- causes a decrease in soil temperature, thus reducing root growth, which creates a shallow root structure.
- leaches nutrients and pesticides from the root zone to groundwater.
- negatively impacts yield.
- wastes water and energy resources.

Excess water and/or water logging can be due to a combination of poor irrigation management and/or above-normal rainfall. Poor irrigation management, especially in above-average rainfall years, increases the potential for negative impacts.

Over-irrigation can increase the potential of crop yield losses from fungal and bacterial foliar and root rotting diseases. High humidity, and often excess water in and on the soil surface and plant leaves, is necessary for infection to occur. In addition, many of the pathogens depend on splashing water to move them from the infected plant surface to other leaves and plants. With excess water, the potential for runoff increases and this can increase the potential of spreading soil-borne pathogens in the runoff water across the field and to other fields. Excess water can also increase insect and weed issues.

Oxygen Content and Microbial Activities Under Wet Soil Conditions

Maintaining adequate oxygen in the crop root zone is critical for healthy crop growth and yield. Plant roots need oxygen. When soil is too wet or waterlogged, the oxygen content is reduced and minimal oxygen is absorbed by the plant roots. With excess water, plant beds may behave like sponges in a bowl of water, holding in water and excluding oxygen. When oxygen is limited, microorganisms compete with plant roots for available oxygen. Also, since the oxygen is limited, microorganisms may turn to pathways of metabolism that can affect the availability and uptake of certain plant nutrients.

One of the most common symptoms of limited oxygen content in wet conditions is the yellowing and dying (leaf chlorosis and necrosis) of lower leaves on the plant. Some researchers have attributed this to the upward movement of toxic substances from the dying roots. However, other researchers have concluded that leaf chlorosis results from a lack of some essential substance in very wet conditions. One of these substances is *cytokinin*, which is ordinarily synthesized in the roots and translocated to the upper portions of the plants. These nutrients are mobile elements that can be translocated from older to newer leaves if their supply from the soil becomes limited and the young leaves become deficient. Translocation depletes the older leaves of essential nutrients, leading to chlorosis and necrosis. Diagnosing nutrient deficiencies can be difficult because other problems can cause similar symptoms.

Wet soils are usually unfavorable for most beneficial bacteria because when pore spaces fill with water, soil aeration reduces. In general, for row crops, including corn and soybeans, wet conditions and/or free water must be present in the field from 24 to 48 hours or more (depending on the degree of soil wetness, temperature, and organic matter content) before the oxygen levels in the soil are reduced to levels detrimental to plant growth. The amount of time it takes depends on the depth to water table, soil type, the fraction of the soil volume occupied by air, the initial oxygen content of the soil air, the rate of oxygen consumption from the soil structure, the rate of drying, and soil temperature.

In a warm soil with high organic matter content (i.e., more than 3.0 percent), the organic matter may decompose more easily and the rate that oxygen is used may be so rapid that the reserve oxygen supply is exhausted in a short time. If the soil drains within 24 hours, the plants usually recover with little or no obvious injury, although it is reported that only 24 hours of flooding can reduce the yield of some crops.

The rate of oxygen use in soil containing actively growing plants is 3 to 6 pounds per acre per hour. Researchers have found that oxygen levels of less than 10 percent in the soil atmosphere may inhibit plant growth. It is reported that corn and soybeans can tolerate up to 20 percent soil carbon dioxide concentration. Under well-managed soils, the carbon dioxide concentration rarely exceeds 5 percent to 10 percent. Researchers also have found that root growth is more likely to be limited by a low concentration of oxygen than by a high concentration of carbon dioxide.

Most arable soils, in the absence of a growing crop, accumulate nitrate nitrogen, sometimes as much as 100 lb/ac. This nitrogen may be removed from the soil by leaching when excess water is present. However, nitrogen also may be lost from the soil by the process of bacterial denitrification. This occurs when the supply of oxygen in the soil becomes inadequate for microbial activities. In this case, the nitrate nitrogen is converted to gaseous nitrogen, which in turn escapes from the soil to the atmosphere.

Wet Soil, Inadequate Oxygen, and Carbon Dioxide Balance Affect Crop Yield

Researchers have found that reduced oxygen concentrations in soil due to wet conditions can cause stomatal closure of plants, which causes stress because plants cannot transpire water at an optimal rate although water is available. Some researchers have reported that the soil oxygen deficiency can cause stomata closure even when no plant water stress exists. Stomata closure reduces the transpiration rate and yield, because transpiration and yield are strongly and linearly correlated.

Most crops are sensitive to very wet conditions and yields can be impacted significantly. Flooding causes greater crop yield losses when it occurs early in the season. The degree of this impact varies with the crop and many other conditions.

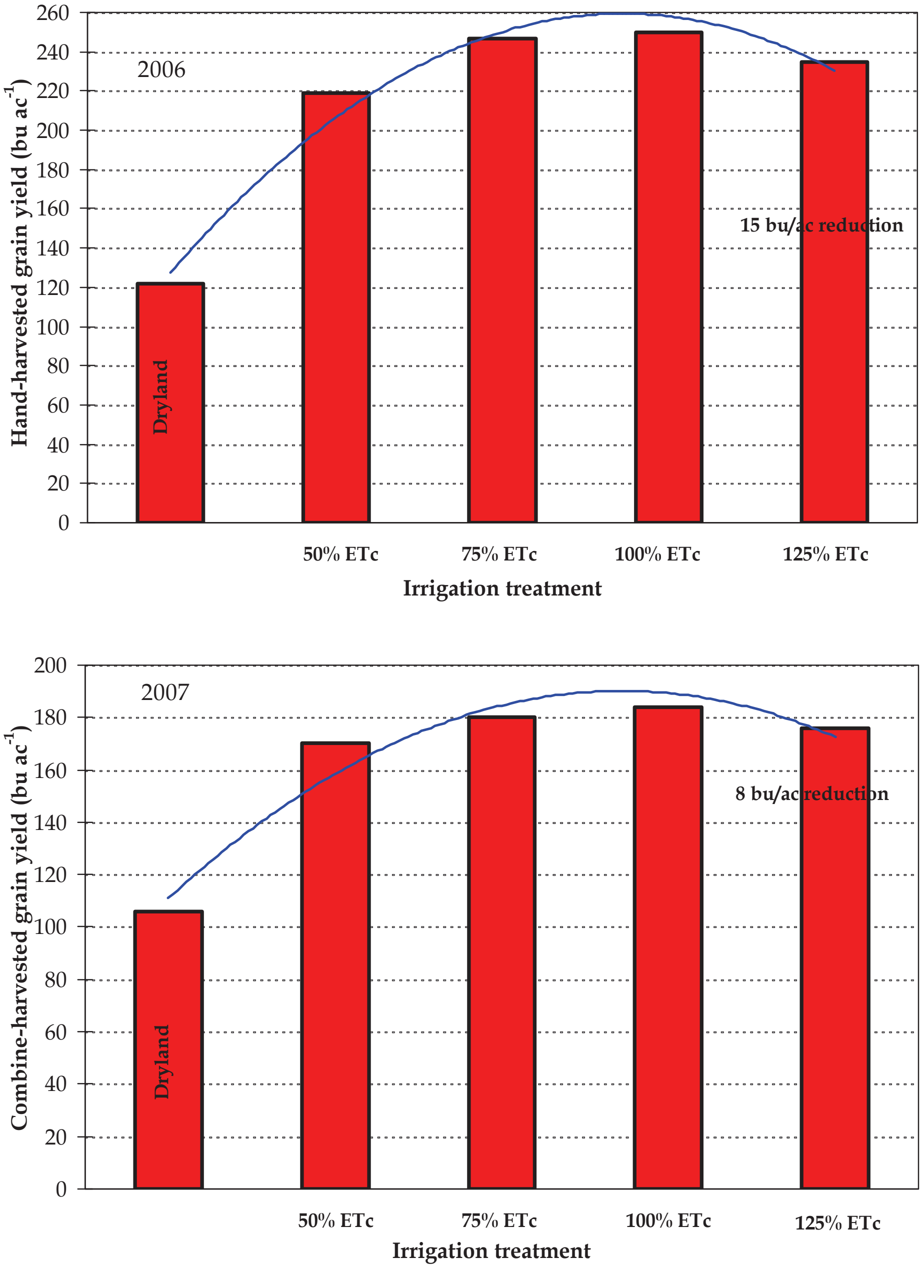

Figure 1. Corn yield response to different levels of irrigation, including an over-irrigated plot (irrigations were replenished at 125 percent of the actual crop water use rate, evapotranspiration) at the University of Nebraska–Lincoln, South Central Agricultural Laboratory near Clay Center, Neb. Plots were irrigated using a subsurface drip irrigation system.

Sorghum generally will tolerate very wet soil conditions, and even flooding, for longer periods than corn. Over the years, researchers have reported that flooding or wet conditions have resulted in yield reductions of between 7 and 30 bushels per acre for row crops, including corn and soybeans. Researchers found that when 6-inch tall corn was flooded for 24, 48, and 72 hours, corn yields were reduced by 18, 22, and 32 percent at a low nitrogen fertilizer level. At a high nitrogen level, these reductions ranged from less than 5 percent to 19 percent. Researchers also have found that when 30-inch tall corn was flooded for 24 and 96 hours, yields were reduced by 14 to 30 percent. In some cases, researchers have reported very little yield reduction even with 96 hours of flooding with a high level of nitrogen in the soil. Some researchers reported that when corn was flooded near silking stage, no yield reduction occurred at a high nitrogen level, but yield reductions up to 16 percent occurred with 96 hours of flooding at the low level of nitrogen. These results show that the nitrogen content during the flooding or wet soil conditions has a significant impact on the magnitude of yield loss.

Related Research

At the University of Nebraska–Lincoln, Institute of Agriculture and Natural Resources, South Central Agricultural Laboratory, near Clay Center, Neb., a research project was carried out in 2006 and 2007 to quantify the impact of over-irrigation on crop yield. The research was conducted on a subsurface drip-irrigated field with continuous corn. The soil at the experimental site is Hastings silt loam with a field capacity and permanent wilting point of 0.34 and 0.14 m^3m^{-3}. The soil consists of 15 percent sand, 62.5 percent silt, 20 percent clay, and 2.5 percent organic matter content. Plots were irrigated at different levels of actual crop evapotranspiration (ET_c) to quantify crop response to different irrigation levels. Corn was planted on May 11 and emerged on May 20, 2006. In 2007, the crop was planted on May 11 and emerged on May 19. The planting population was approximately 30,000 plants/ac in both years.

In 2006, a total of 3.6, 5.4, 7.2, and 9.0 inches of irrigation water was applied to 50, 75, 100, and 125 percent of the ET_c treatments. In 2007, a total of 3.1, 4.6, 6.1, and 7.6 inches of irrigation water was applied to the same treatments. From May 1 until September 30, there were a total of 15.5 and 18.7 inches of rainfall in the 2006 and 2007 growing seasons. Yield results from different irrigation treatments are presented in *Figure 1* for both years. Each bar on the figure is an average of three replications for each treatment. Each replication (plot) was 400 feet long by eight-rows wide with a 30-inch row spacing. When considering at least 2.2 inches per foot of available water that is typically held by a Hastings silt-loam soil from spring moisture, in addition to the irrigation and rainfall amounts, it is evident that the 125 percent ET_c treatments were over-irrigated in both years.

The yields for dryland, 50, 75, 100, and 125 percent ET_c treatments in 2006 were 122, 219, 247, 250, and 235 bu/ac. In 2007, yields were lower for all treatments due to a wind storm in late August. The yields for the same treatments, respectively, were 106, 170, 180, 184, and 176 bu/ac. In both years, over-irrigation of the 125 percent ET_c treatment resulted in yield reduction of 15 bu/ac (6 percent) in 2006 and 8 bu/ac (4.3 percent) in 2007 as compared with the "optimum" or fully-irrigated 100 percent ET_c treatment. These findings agree with the over-irrigation impact on grain yield of corn that has been reported by other researchers. When current commodity prices are considered, yield reductions of 8 or 15 bu/ac ($43.00/ac or $81.00/ac with current grain prices) are significant and can impact the farm profitability substantially. Thus, proper irrigation management can reduce the risks of negative impacts of wet or waterlogged soils associated with over-irrigation and/or caused by above-average rainfall.

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Issued December 2008