Maximizing Production in Drought Stressed Environments
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Current professional work / research interests:

I am a seed salesman by profession, but have a passion for helping the farmers maximize their yields in an economical and environmentally friendly manner.
A Little About Me

• I have been married for 3 years
  • Wife: Tracy
  • 2 Daughters: Teeghan (2) Taryn (9 mo)

• Spent my entire life around farming

• Grew up on a 60 cow dairy north of Hull, IA
  • Quickly realized I loved farming, but not a deep love for dairy

• Went to SDSU and got an Agronomy Degree

• Began working at Precision Ag Service selling Pioneer Seed
Topic Selection

• We have Highly Variable Soils

• Lots of Livestock

• Realized that not all fields were created equal when drought stress occurred

• Most people know that potassium fertility and residue cover helped when drought struck
  • I felt an in depth understanding of why they helped and what made them benefit in decision making
Why A Learning Module

• Personal Goal - Getting a Masters Degree was to help farmers make better decisions
  • Best way to help them is to help the people who are advising them.

• I felt there was a lack of understanding as to why organic matter, residue cover, potassium fertility, etc was showing better yields.
About The Learning Module

• 3 Major Areas of Focus
  • Residue Cover
  • Soil Organic Matter
  • Potassium Fertility

• These 3 areas are discussed in how to achieve 2 goals
  • Maximize Plant Available Water
  • Help the Plant Maximize the Water Use Efficiency

• Brief discussion about hybrid/variety selection and genetic drought tolerance
Module Introduction

It is no mystery that the most limiting factor in crop production is water. Whether it is dry-land production where Mother Nature is providing all of the water for the growing crop or areas where the amount of water available for irrigation is limited, we can dramatically benefit from helping our crop be more productive when the water is limited.

In this learning module we will look at management decisions that should be considered in order to maximize the crop production in drought stressed environments. We will discuss not only the factors that should be managed, but also look at why these management decisions will benefit the growing crop. We will focus on two main sections for this learning module, providing maximum plant available water and maximizing the efficiency of the water that is available.
# Module Contents

**Maximizing Available Water for the plants**
- Water Infiltration Rate
- Water Holding Capacity

**Helping the plants make the most of the Plant Available Water**
- Potassium Fertility
  - Stomatal Regulation
  - Maintenance of Gradients
- Hybrid/Variety Selection

**Summary**

**References**

**Quiz**
Maximizing the amount of Plant Available Water

Background Information
There are three basic ways for water to leave the soil profile once it has infiltrated the ground:

- Water that is over the field capacity of the soil will simply percolate through the soil profile.
  - This water would most likely create anaerobic conditions in the root zone and be detrimental to the crop

- Water can also evaporate from the soil surface and be lost into the atmosphere.
  - Tillage passes can move dry soil from the soil surface down into the soil profile, and move soil that is moist that was down in the profile up to the soil surface.

- Water is transpired through the plant.
  - Either through the intended crop in the field or through weeds in the field.
What Is Water Infiltration Rate?

Water infiltration rate is the amount of water that is able to move into the soil profile over a given amount of time. If water is not able to penetrate the soil surface it will runoff the soil surface into bodies of water.

The next question becomes, “How do we get the most water infiltration?”

There are several factors to be considered when looking at water infiltration rate:

• Slope

• Residue cover

• Soil bulk density

• Soil Organic Matter

• Hydraulic Conductivity

• Plus many others

(Illinois State Water Survey, 2014)
Water Infiltration Rate

Since we are not able to change soil characteristics such as surface slope and coarseness of the soil through management practices, we will only focus on the factors that management decisions can impact.

In this learning module, we will discuss the impacts of the following on water infiltration:

- Residue Cover
- Soil Organic Matter
- Soil Tillage
- Hydraulic Conductivity
- Soil Compaction
Residue cover slows down the water as it is flowing across the soil surface by acting as a physical barrier to the moving water.

The benefits of slowing down the speed of the flowing water include (Jasa, 2013):

- More time for water to infiltrate the soil surface
- Reduces the amount of erosion that occurs on the soil surface
- Allows time for suspended soil particles to be deposited back in the field

The slope of the land will also have an impact on the speed at which the water travels across the soil surface.
Water Infiltration Rate

Residue Cover

Residue Cover also prevents raindrops from directly impacting the soil surface.

When rain drops impact soil particles, it causes individual soil particles to break apart from other soil particles, which can lead to:

- Soil particles filling up the pore space of the soil at the soil surface, therefore reducing the water infiltration rate of the soil.
- Increased risk of water erosion from the soil surface.
Increasing the organic matter in the soil will have positive benefits to the water infiltration rate of the soil (Fenton et al., 2008)

• Increasing the organic matter of the soil will help the soil to develop better soil structure with benefits that move beyond water infiltration rates

• Well structured soil:
  • Has better pore space vs. soil particle ratios
  • Increased aggregate stability to resist soil erosion and maintain optimal pore space
  • Improved Hydraulic Conductivity
Water Infiltration Rate

Soil Tillage

Tillage passes have a strong negative impact on the natural soil structure

- The tilled soil will have lower aggregate stability and be more prone to erosion
  - Leads to loss of nutrients and Organic Matter (Al-Kaisi and Leight, 2005)
- Allows rain drops to directly impact the soil particles on the soil surface
- Pore space is reduced leading to significantly lower infiltration rates
- Increased residue decomposition rates
  - Lowers the amount of organic matter in the soil long term

Image Credit: www.caseih.com
Water Infiltration Rate

Soil Compaction

There are however instances where tillage will be necessary for improvement of water infiltration rate. If there is excessive soil compaction in the field, tillage may be beneficial for increasing the infiltration rate of the soil.

Since soil compaction decreases the size and quantity of the pores in the soil profile, increased compaction of the soil will slow the infiltration rate of the soil. Compaction essentially takes a well structured soil, and makes it a poorly structured soil as the image on the right shows.

(DEPI, 2014)
Water Infiltration Rate

Soil Tillage

• UNL study showed that water infiltration in no-till soils were 10 times faster in no till soils versus tilled soils (Jasa, 2013).
  • .4” per hour in conventional tilled soils
  • 4” per hour in no tilled soils
  • Generally we will find that the rate on conservation tillage in between the infiltration rate for the no till and the rate for conventional tillage (Jasa, 2013).
  • Soil texture will also have a very large impact on the infiltration rate for the soils
    • However management of the soils has no impact on the soil texture

Obviously maximizing the amount of water that can infiltrate the soil surface should be a major concern. So far we have focused on the factors at the soil surface. There is one more factor that needs to be discussed that is not at the soil surface, it is the rate that water is able to move through the entire soil profile, or the Hydraulic Conductivity of the soil.
Water Infiltration Rate

Hydraulic Conductivity

If water moving through the soil profile hits a layer of soil that the water is not as able to move through, it will hold up the water higher in the soil profile. Water is only able to move through the soil profile at the pace it can move through at the slowest point in the soil profile. Therefore if there is a layer of compaction for example that limits how fast water can move through it, the water above this point will be held up, and if this backlog reaches the soil surface, it will also limit the amount of water that can infiltrate into the soil.

The management of the soil will play a large factor on the hydraulic conductivity of the soil. Things such as compaction, organic matter content, and depth of soil will all have an impact on the hydraulic conductivity of the soil.

(USDA, 2014)
Water Holding Capacity

Once the water has moved into the soil, we will now look at the factors that will help to hold the water in the soil. Remember from earlier that the 3 ways for water to leave the soil profile:

1. Percolation through the soil profile
2. Evaporation from the soil surface
3. Transpiration through plants

Characteristics of the soil such as the texture will play the largest role in the amount of plant available water it can hold, but due to the fact that management decisions will not impact the soil characteristics we will not spend much time discussing them (Sullivan, 2002).

Instead we will cover the areas of the soil that our management decisions can have a positive impact on. The soils organic matter content and residue cover can play a large role in the amount of water that it is able to hold for the growing crop.
We want to focus on the amount of plant available water that the soil can provide. The chart to the right shows that not all soils are created equal.

Clay particles are very small and have a high amount of surface area for water particles to adhere to. The closer the water particles are to the individual soil particle, the more tightly it is held.

- Clay soils have a high water holding capacity, but because of the particle size the water is held closer to the soil particles, and therefore held tighter and raising the wilting point of the soil.

- The highest plant available water levels are found in loam – silt loam soils

(soilquality.org.au, 2014)
For every percent of organic matter in the soil, 16,500 gallons of water are held that are available for plant usage (Sullivan, 2002).

In order to maximize the amount of organic matter in the field, let's review the sources of organic matter (Fenton et al., 2008):

• Plant Residue from harvested crop
• Cover Crop residue
• Manure
• Compost

Leaving plant residue on the soil surface will provide the maximum benefit on the organic matter of the soil. However in the circumstances where this is not practical, silage harvest for example, the addition of cover crops and manure should be considered in order to help maintain the organic matter levels in the field.
Residue Cover

While residue cover is one of the largest hindrances around planting time, because it keeps the soil cooler and preserves moisture, these are the benefits that we are looking for after the crop has emerged if drought stress is a concern.

Since residue acts as a physical barrier for the soil, it is basically a protective blanket for the soil to protect it from the outside world. When the sunlight’s energy is reflected back into the atmosphere instead of reaching the soil surface, there is less energy available to evaporate water from the soil surface.

Not only does the residue block the sunlight and prevent it from reaching the soil surface, it also prevents wind from reaching the soil surface. This will also help prevent the evaporation from the soil surface (Jasa, 2013).
Residue Cover

Soil Organic Matter

• Maintenance of residue cover will provide the highest levels of soil organic matter.
  • There are two factors that make residue cover important when looking at organic matter in the soil
    • Residue in the field provides the soil the material that becomes organic matter in the soil as the soil breaks it down
    • Residue reduces soil losses from wind and water erosion
      • It provides a physical barrier that prevents wind from reaching the soil surface
        • As soil is eroded from the soil surface, the higher organic matter soil is closest to the soil surface, and is the soil that is lost to erosion
      • It also slows the flow of water over the soil surface and allows soil particles that flowing water has picked up to be deposited back into the field
Maximizing use of Plant Available Water

Potassium Fertility

Once we have given the plant as much water as we can, we should then focus on how the plant can best use the water that it has available. When water is limited the plant’s ability to uptake nutrients is also limited, since most nutrients are carried into the plant by water.

Nutrients such as nitrogen and phosphorus are both essential for healthy plant growth as well as yield potential when drought stress is present. Yield can be limited by either nutrient in drought stress, but Potassium fertility becomes very important in times when the plant becomes stressed from drought.

In this section of the learning module, we will focus on how keeping adequate potassium fertility, can help the plants be more productive in drought stress. Potassium has many roles in the plant that make the plant more efficient in times of drought stress.
Roles of Potassium in the plant

Since potassium is considered a macronutrient in the plant, sufficient levels are essential for maximum yield even when there is not drought stress. However, with the critical roles that potassium has in the plant, adequate levels in the soil are even more important when there is drought stress. In fact, according to Sabanci University in Turkey, plants that are under drought stress require higher levels of potassium than plants that are not under drought stress (Cakmak, 2005). Potassium is used in the plant for root elongation, which allows the plant to reach more water in the soil, and regulating water movement throughout the plant.
The first role of potassium in the plant that we will discuss, is its effects on roots. Potassium has been shown to impact the amount of root elongation (Wang et al, 2013). When water is limited, the ability of the roots to explore more soil volume is very critical, it allows the plant to more easily access nutrients and the soil water that is available. Nutrients in the soil are not as easily brought into the roots when the soil is dry because water is often used to carry nutrients into the root. This ability to explore more volume of soil then becomes very critical to attain adequate amounts of nutrients.

Once the plant has taken in as much water and nutrients and water as the soil will allow, we will look at how potassium will impact water in the rest of the plant.
Potassium

Transpiration Regulation

The transpiration process is very important for many factors within the plant. The plant relies on this process to move water, nutrients, amino acids, and many other compounds throughout the plant. It is also important for the plant to cool itself and prevent cell damage from excessive heat. The regulation of this entire process is controlled within the plant with potassium.

In the next couple slides, we will look at how the specific roles that potassium plays in the regulation of water in the plant. How it regulates the stomata, which controls the whole transpiration process, and how it this in turn creates water gradients that are used to move water through the entire plant.
Potassium

Stomatal Regulation

• Potassium ions in the plant are moved into the guard cells that protect the stomata. 
• The potassium ions create a water potential gradient that causes water to move into the cells. 
• As the water fills the cells, they expand, and force open the stomata. 
• The process is reversed when the stomata are closed
  • The K ions are moved out, and the water potential gradient is lost, so water leaves the cells 
  • When potassium fertility is limited, processes that control the stomata are slowed (Phosphate & Potash Institute, 1998) 
  • This slows the process of the plant shutting down to conserve moisture 
    • When stomata close, photosynthesis stops 
    • Opening of the stomata is also slowed
Potassium

Stomatal Regulation

Research at Lincoln University was conducted on Hibiscus Plants showed that plants that were deficient in potassium had lower rates of photosynthesis, transpiration, and had lower overall water use efficiency than plants that had adequate levels of potassium (Egilla, et al, 2005).

This study also showed that the leaf water content in the leaves of the Hibiscus plants that were subjected to drought stress was higher in the plants that received potassium treatments compared to those that did not (Egilla, et al, 2005).

The leaves having higher water content, as well as higher rates of photosynthesis would indicate that the leaves of plants that were given additional potassium were better able to use the water that was available, and that it was able to keep the stomata open for longer periods of time than were the plants that did not have adequate potassium fertility. We need to remember that when the stomata are forced to close during times of drought stress, photosynthesis within the plants stops.
The water movement through the entire plant is driven by the transpiration process. When water leaves through the plant through the stomata the water is pulled through the plant by water potential gradients.

As the water evaporates from the leaf surface, the water potential is lowered, and water tension, as well as the decreased water potential creates a pull of water back into the leaf from the xylem. This pull continues throughout the plant all the way back to the soil.

(Boundless.com, 2014)
Potassium

Water Movement Gradients

This pull of water through the plant is vital to the plants ability to work efficiently. The water that is pulled through the plant is used to carry nitrates, phosphates, calcium, and magnesium through the plant via the xylem (Potash & Phosphate Institute, 1998).

With all of these systems working together and all dependant on sufficient levels of potassium, it is easy to see that potassium has a crucial role in making plants more efficient when there is drought stress.
Maximizing use of Plant Available Water

Hybrid/Variety Selection

The final piece we want to look at is the drought tolerance of the genetics we are planting. Each field has its own unique needs for genetic traits, but drought tolerance should be highly considered when looking at genetics for fields that have a higher likelihood of seeing drought stress in the growing season.

Managing the potassium fertility will not have an impact on the genetic drought tolerance of the crop. Adequate potassium fertility will provide benefits regardless of the genetic drought tolerance; as well as having as much water available for the crop.
Summary

Making a field produce better under drought stress is not a rapid process. Each management decision you make will impact your field for many years to come. There is not one exact plan that will work for every field. But understanding how certain factors impact the drought tolerance of the field as a whole can lead to better management decisions and better production of the field when drought stress does occur.

Increasing organic matter in the soil, maintaining adequate potassium fertility, and keeping residue cover will all help the fields be better able to tolerate drought stress and yield better when drought stress does occur.
References


References (Cont)


It’s most efficient to submit the quiz questions in a Word Document. Questions must be multiple choice, with only one correct answer. Indicate the correct choice using an *. It does not matter what order you put the answer choices in, because the quiz generator used in the actual module will automatically switch the answers around each time the user tries the quiz.