3 - Drainage and Irrigation

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Drainage

Adequate drainage is necessary for maximum corn production because water-logged soils reduce yield. It is highly recommended that corn be planted on raised rows or beds, especially on fields that are relatively flat. Corn is typically planted early when low temperatures and significant rainfall are likely. Raised rows or beds reduce the effect that cold, wet soil conditions have on planting and early crop development. Rolling fields that have significant slopes may not need raised rows or beds for drainage, but may still benefit from the beds warming up faster than flat seed beds. Poor drainage hampers field operations from field preparation through harvest and limits the effectiveness of irrigation and reduces overall yield potential. Water infiltration is also reduced because of compaction if soil is tilled when the moisture is too high. Good field drainage complements all crop production practices and makes it possible to utilize reduced or no-till corn production systems. **The goal for drainage is to have minimal standing water on a field 24 hours after a rainfall or irrigation.**

Surface Drainage

Field surface smoothing and forming, prior to bedding, can improve the surface drainage of a field. Use land planes to smooth out the high spots and fill in the low areas so that the field has a more uniform slope toward drainage outlets. Low areas that are larger than 100 feet across or that require more than 6 inches of fill should be overfilled and compacted before being planted. Make an effort to accurately determine a field's drainage flow pattern. Deciding where water will drain by simply looking at the field is not always easy. Some limited surveying of field elevations can be very helpful in determining where to place tail water furrows and field drain outlets.

Precision grading of a field provides a positive method of improving surface drainage as well as making furrow irrigation possible. If a field is being considered for precision grading, the soil should be evaluated to determine what problems might occur if deep cuts are made in some areas. The cut areas may expose soil with reduced production capability. County soil survey reports, published by the Natural Resources Conservation Service (NRCS), can help identify soils with unproductive subsoils.

Precision grading can be done with laser or Global Positioning Equipment. There are two types of precision grading, constant slope and warped surface grading. Constant slope grading holds a constant slope in one direction and grades the second direction.

Warped surface grading uses a computer program and GPS data to develop a grading surface that minimizes the amount of earthwork needed to provide positive drainage in 1, 2 or more directions. This approach can also include limiting water velocities so that erosion is minimized. Warped surface grading in many cases is more cost effective than constant slope grading. **If possible, the finished grade in the primary slope direction should range from 0.1 to 0.5 per cent (% 0.1 to 0.5 ft. per 100 ft.)**. This range provides good surface drainage without increasing erosion potential. Slopes of less than 0.1 percent are suitable for cross slopes but should be limited to slope lengths of a quarter mile or less. Slopes less than 0.1 percent are more difficult to construct with precision, and they tend to develop more low areas and reverse grades. It is also preferable consider putting a field to grade in only one direction (i.e., zero cross slope) if cost effective. Settling often occurs in deeper fill areas and should be "touched up" before bedding if possible. The land grading design should consider the type of drain outlets and the number required for the field. It is best to provide an outlet point for every 20 acres.

An elevation survey of the field is required before any design work can be done. Survey information can be entered into a computer program that evaluates possible drainage options for a field and determines the cuts and fills required. Most land grading contractors offer the computer program design, and it is sometimes available through NRCS. The lowest expected elevation of the field should be determined before grading begins to assure that water will drain into the surrounding ditches adequately and not back up onto the field. It may be necessary to divide the field into shorter segments to ensure that the runoff leaves the field. Precision grading is usually expensive and is a long-term investment for increasing production efficiency and potential and the market value of the land. Government funded conservation programs sometimes offer cost sharing on precision grading and/or other conservation best management practices. Information on these programs can be obtained through NRCS.

Good surface drainage is even more important if corn is planted flat rather than on raised rows or beds. Low areas in a flat-planted field are likely to have poor production for obvious reasons. Drain furrows to these areas can be used to reduce the effect on the crop. Shallow and narrow drain furrows can be constructed with several different types of equipment. The equipment should spread the soil evenly away from the drain furrow, so flow into the furrow is not restricted. Construct drain furrows in the low areas of a field rather than putting them in randomly. They should generally run with or at a slight angle to the natural slope of the field but not across the direction of the slope. Furrows should have continuous positive grade to assure that the water will be directed off the field. A drain furrow is not complete until it is connected to a ditch or pipe of adequate size to carry excess water away from the field.

An important component of field drainage is the ditch system that receives the excess water and carries it away from the field. Flow restrictions in these ditches can cause excess water to remain on a field. Drainage ditches should be maintained and routinely cleaned out to effectively handle the drainage water from a field. **No tillage, cover crops or reduced tillage limits the sediment leaving fields and minimizes the sedimentation that occurs in drainage ditches**. Ditch outlets and drainage structures should also be checked to assure that they are functioning properly and are not becoming restricted. It may be necessary to work with neighboring farms and/or the Drainage District to correct common drainage problems. Planned drainage improvements could impact areas classified as wetlands. If this possibility exists, contact the local NRCS staff to see what help they can provide. Typically, they can visit the site and determine if there are drainage restrictions.

Internal Drainage

Many Arkansas soils, with the exception of the sandier (coarse) soils, have limited infiltration and/or internal drainage. Some clean-tilled silty soils tend to seal or crust over at the surface after rainfall or irrigation, restricting the movement of water into the soil surface and the root zone. Infiltration may be improved through crop residue management. Maintaining crop residue reduces surface sealing and crusting so water moves into the soil more freely. This improves the infiltration and water-holding capacity of the soil.

Naturally occurring restrictive soil layers and those formed by tillage equipment restrict internal soil drainage. The restrictive soil layers reduce the rooting depth and water reservoir available to the corn plant. Shattering these layers prior to planting a corn crop is recommended to improve plant root development and internal drainage. A soil probe or shovel can be used in several areas of a field to determine if restrictive soil layers are a problem.

Digging up root systems and observing the rooting depth and pattern can also help determine if there is a restriction. Restrictive soil layers are commonly shattered by using a subsoiler or ripper-hipper in the field. The depth and thickness of the restrictive layer usually determines which implement should be used. **The restrictive layer must be dry enough for the deep tillage implement to extend just below the bottom of the restrictive layer so it is effectively lifted and shattered**. If the restrictive layer begins at 8 inches and is 2 to 3 inches thick, the tillage shank must penetrate 10 to 12 inches deep. In-row subsoiling is more effective than random subsoiling paths due to the re-compaction caused by subsequent trips of the implement. The in-row pattern also reduces the likelihood the field will be too soft in the spring to support equipment and delay early field preparations. High-residue sub-soilers or ripper-hippers are suggested for main taining he same row location year to year. Surface tillage, especially disking, quickly reforms restrictive layers and should be avoided, if possible. Once tillage pans have been removed with deep tillage implements, use no-till or minimum till systems to keep tillage pans from re-forming.

Irrigation

Corn production in Arkansas is only recommended with irrigation. Reasonable corn yields may be obtained without irrigation in some years that have good rainfall patterns and growing conditions.

However, if adequate rainfall does not occur, yields can be very low and the drought stress can contribute to charcoal rot and aflatoxin. These potential risks are the basis for the strong recommendation to irrigate corn in Arkansas.

Yield

Experience by Arkansas farmers in recent years has demonstrated that hybrids adapted to this region under irrigation can yield 200 plus bushels per acre. Corn yields from the Arkansas irrigation yield contest for 2018 and 2019 have averaged 219 bu/ac, using on average 10.5 inches of irrigation. **Irrigated corn should yield between 200 and 225 bushels per acre using about 15 acre-inches/acre of irrigation with good production practices and irrigation management on productive soils.**

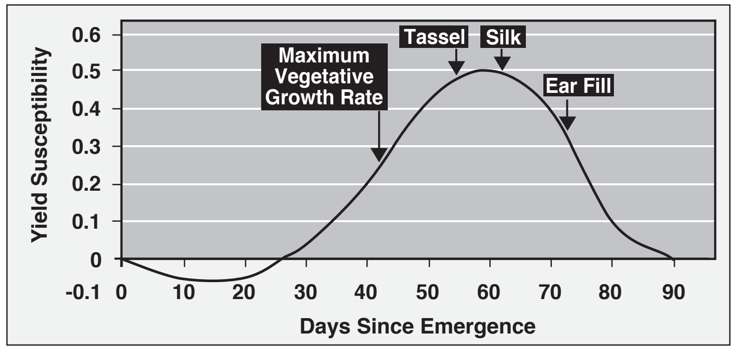

Figure 3-1. Yield Susceptibility for Corn (from Sudar et al., 1981).

Water Needs

The total amount of water or potential evapotranspiration that a corn crop needs during the growing season on average in Arkansas is between 23 and 26 inches. Most Arkansas farmers are averaging a total of 27.5 inches on average (rain plus irrigation) under well managed irrigated fields to maximize yields. Factors such as weather conditions, planting date, plant density, soil type, and days to maturity also play a role in water use. This need is reduced by rainfall. Irrigation needs are between 14 to 26 inches on average (Table 3-1). Producers can expect that between 85 and 93% of rainfall during the season is useable to meet crop water demand, although severely sealed soils will not be capable of such high capture. Planting in early March can result in about 4 inches (ac-in/ac) less irrigation needed or about two less irrigations than planting in early May or June.

Table 3-1. Irrigation water needs based on planting date and system efficiency in acre-inches/acre (inches of water)

	Irrigation System Efficiency				
Planting Date	50%	60%	70%	80%	90%
1-Mar	17.3	14.4	12.4	10.8	9.6
1-Apr	21.7	18.0	15.5	13.5	12.0
1-May	26.0	21.7	18.6	16.2	14.4
1-Jun	26.0	21.7	18.6	16.2	14.4

*Assumes 120 day maturity corn, irrigation is triggered at critical depletion with 2” applications, and silt loam soil. Data generated using FAO56 (Smith, 1992; Allen et al., 1998).

Accounting for irrigation inefficiencies for timing, deep percolation, and application efficiencies irrigation water needs are between 10 and 26 inches. For furrow irrigation systems with 60% efficiencies, the range is between 14 and 22 inches depending on planting date and other factors. Table 3-1 shows how planting date and irrigation efficiency impact irrigation water needs. Expect most furrow irrigation systems to perform between 50%-70% efficiency and center pivots to perform between 60% and 85% efficiency. Thus a good target for irrigation demand is 15.5 inches for an April 1 planted crop and moderately efficient furrow irrigated system at 70% efficiency (Table 3-1).

Furrow irrigation systems should be capable of applying 2.5-3 acre-inches/ac application depth within a maximum of 30 hours and 24 hour sets are recommended. If this is not possible, reduce set sizes to reduce pumping times.

Moisture stress any time after planting can affect plant development and reduce yield potential, however stress during the tassel and silking stages are the most sensitive (Table 3-2). Figure 3-1 shows the general relationship of potential yield reduction due to moisture stress at different growth stages. Data from deficit irrigation studies report little yield response for water stress in the vegetative growth stage for corn.

Corn’s daily water needs are relatively low in the first 3 to 4 weeks of vegetative growth, and rainfall is usually adequate to meet the water demand during this period. However, if it is relatively dry when the crop emerges and rainfall does not occur in the first 2 to 3 weeks, irrigation may be needed. When the corn has approximately 8 fully developed leaves, its growth rate greatly increases. The number of kernel rows per ear is determined at this time so plant stress needs to be avoided during this period. A side-dress fertilizer application is usually made prior to this time. The plant's nutrient and water uptake increases, and irrigation may be needed at this time to activate the fertilizer and avoid moisture stress.

Table 3-2. Potential Yield Reduction from Moisture Stress at Different Growth Stages of Corn	
Growth Stage	**% Yield Reduction**
Prior to tasseling	10-20
Tasseling to soft dough	20-60
Soft dough to maturity	10-35

If nutrient and water needs are met, rapid plant growth continues. The number of kernels on each ear and the size of the ear are being determined when the plant has 12 leaves. The number of kernels is determined by the 17-leaf stage, which is about one week from silking. At this time the crop is very near the start of the reproductive growth stage, when its water needs are greatest. **During the period from about 2 weeks prior to silking until 2 to 3 weeks after silking, the water use on days with hot summer temperatures can be 0.3 inches. This 4 to 5 week period is the most critical time to make sure irrigation is applied as needed to satisfy the crop needs**. Stress at this time can delay silk elongation and development and lead to poor pollination resulting in reduced seed set. A good goal is to have adequate soil moisture 1 week prior to tasseling until grain fill. Moisture stress during the silking stage may delay development so that the pollen is shed before the silks emerge. Irrigation frequency should be at the highest during this time, and if dry conditions exist irrigation should be initiated to ensure that soil water is in good supply for silking.

Once the grain is developed, the water use begins to decrease because the kernels start to progressively harden as they dry and the crop approaches maturity. Table 3-3 shows the estimated range for daily crop water use as the crop develops. Irrigation frequency should be reduced once ear fill has been reached.

Table 3-3. Estimated Corn Water Use in Arkansas*	
Days After Planting	**Inches Per Day**
0-30 (early plant growth)	0.05-0.10
30-60 (rapid plant growth)	0.10-0.20
60-100 (reproductive stage)	0.20-0.30
100-120 (grain fill to maturity)	0.25-0.10

*Based on planting date of April 1.

Irrigation Scheduling

The timing of irrigation is commonly referred to as irrigation scheduling. Correct timing is critical to maximizing yield. **Having the ability to irrigate is important, but it is also essential that a grower have the ability and commitment to apply irrigation in a timely manner**. Too often, growers irrigate by the appearance of the crop. Visual stress, especially during reproductive growth, can result in yield loss. Even if irrigation is started at the first sign of visual stress, there is still some amount of time required to finish irrigating a field. The result is that the crop in the last area of the field to be irrigated suffers even greater yield-limiting stress.

Irrigation timing decisions can be improved if the soil moisture is known. Determining the soil moisture by visual observation or by kicking the soil surface is difficult and can be misleading. The "feel" method can be used to determine the soil moisture condition more accurately. This method involves using a shovel or soil probe to pull a soil sample from the root area. Sampling should be done to a depth of at least 24 inches. Sampling only the soil surface is not indicative of the need for irrigation. In general, soil moisture can be estimated by forming a ball and ribbon and by appearance. A key to this method is to take samples across the field at different depths in order to better determine the soil moisture for the field. The challenge is to determine when to begin irrigation so the entire field can be irrigated before any part becomes too dry. Satisfactory results with the "feel" method can be achieved with experience. More information on estimating soil moisture by the feel and appearance method and how to use is can be found by searching the internet. Guides show pictures and descriptions for different soil types and percent available water. Irrigation should be triggered between before 50% depleted using this method.

Soil moisture can be determined more precisely with tensiometers, granular matric potential sensors, and volumetric moisture content sensors. Soil water is expressed in soil water content, usually volumetric, and soil water potential. Soil water content is the volume of water per unit volume of soil expressed as a percent.

A tensiometer is a sealed, water- filled tube with a vacuum gauge on the upper end and a porous ceramic tip on the lower end. The tensiometer is installed in the seedbed at a depth where the majority of the roots are located. A 12-inch depth is commonly used for surface irrigation, but if a hardpan exists then the tensiometer is placed just above the restrictive layer. Shallower settings at about 8 inches deep are recommended for center pivots. Two or three tensiometers per field are recommended to avoid a problem should one of the tensiometers quit working. Starting irrigation at a vacuum gauge reading of about 50 centibars on silt loam and clay soils, and at approximately 40 centibars on sandier soils, is recommended.

However, the time and effort that this requires usually results in most producers not being able to use them very effectively. Higher tensions can be used, but after 60 cb tensiometers often break tension and require frequent maintenance, so this is the primary reason they are not used in furrow and sprinkler irrigation.

An easier to use and deploy sensor that measures soil matric potential are granular matrix sensors commonly referred to as Watermark™ sensors model 200SS as shown in Figure 3-2. These sensors are installed in the plant row between plants. They consist of a series of electrodes covered by ceramic shell and membrane and when installed equilibrates to the surrounding moisture content. The sensor measures the resistance of the ceramic material. The range of resistance measured ranges from 0-200 Kpa or centibars of tension in silt loam and clay soils. In sandy soils the range is from 10-200Kpa or centibars (Irmak et al., 2006) of tension.

They report soil water as tension or vacuum which is a measure of the energy that the plant exerts to draw available water from the soil, also referred to as the "soil water potential." Soil matric potential is measured in pressure usually either centimeters of water, bars, or kilopascals, although several other units can also be used. Soil matric potential measurements are inherently a negative value of pressure, however it is common and appropriate to use the inverse positive term of "tension." When soil is saturated, the soil pores are full and the tension is near zero. As gravity pulls the gravitational water from the soil matrix, air is replaced creating a small amount of tension, this threshold is field capacity, typically around 15-35 centibars dependent on soil type. As plants extract water beyond field capacity, they do so until the wilting point or 1500 centibars.

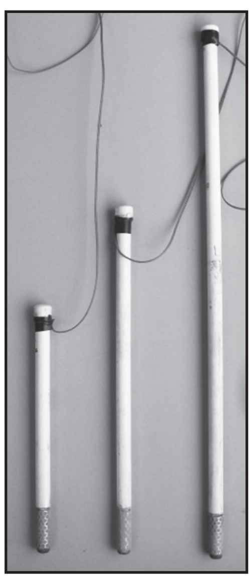

Figure 3-2. Watermark sensors installed on CPVC pipe for installation and different depths.

Soil water content of soils varies by texture, soil organic matter and compaction. Therefore field capacity and the soils ability to hold water vary and must be determined for each installation. In general higher clay content results in smaller pores and a greater ability to retain moisture in the matrix because it takes more energy to extract the water from the matrix. In sandy soils, the pore spaces are large and once the pores are empty, water is easily extracted from large pores, less water is available once the pores have been emptied.

Watermark sensors are best used by gluing them to thin walled PVC or CPVC pipe at several depths to represent the rooting zone of corn. In Arkansas, the recommended installation depths are 6, 12, 18 and 30 inches to represent the top three feet of the profile. An overly conservative threshold is 60 centibars for silt loams and clays and 35-40 cb for sandy soils. Experience has shown that 90-100 centibars is also safe in silt loam and clay soils. More information about using sensors to schedule irrigation is available at www.uaex.uada.edu/irrigation.

Interpretation of the 30 inch sensor should be done with caution as in most cases this water is available but not in all situations. Rarely is this subsoil replenished, so irrigators should use this available water before the end of the season, but generally early consumption indicates inadequate irrigation and if available water remains unchanged it indicates either a pan or over irrigation. Users should monitor trends to observe water use patterns during the year and use their observations to establish acceptable thresholds for their situations.

Additional guidance on Watermark readings and values can be found at www.uaex.uada.edu/irrigation. There are three factsheets available on Watermark™ sensors. They discuss how to build sensors, how to interpret them, and how to use them to terminate irrigation.

- FSA57 "How to Prepare, Test, and Install Watermark™ Sensors"
- FSA58 "How to use a Watermark™ Soil Moisture Sensors for Irrigation"
- FSA59 "Timing the Final Irrigation using Watermark™ Sensors"

For more information about soil moisture sensors see, www.uaex.uada.edu/irrigation and itunes or the google playstore.

There is also a mobile app (Figure 3-3), the Arkansas Watermark Tool, available on the apple app store that can be used to interpret sensor readings. The mobile app does all of the necessary calculations for the user. First enter matric potential readings representative of the rooting depth, select soil type, allowable depletion, growth stage, and irrigation set time. The app will provide the number of days until the next irrigation. The same can be done using the following factsheets.

In addition to soil matric potential sensors, there are many other types of sensors. The most common are dielectric, total domain reflectometry and capacitance (frequency domain) probes. Generally, these are used in conjunction with a telemetry system of some sort so the cost is much higher than Watermark™ sensors. These sensors typically report volumetric water content. The sensors generally use the dielectric properties of soil and water to correlate sensor signals to water content. Capitance sensors report relative values and calibration of the resulting values, while they may be called volumetric water content, are not absolute. Capitance sensors require calibration at every location and soil type to actual response of the crop and water content. Irrigators should use the trends to determine field capacity and wilting point and manage between the reported values for the sensor. Shallowing of the trend (slope decrease) in water content in a layer, is an indication of water stress by the crop. Saturation can often be seen after a significant rainfall, where the upper soil layer is brought to a high-water content and then seeks field capacity after gravity draws the free water from the matrix. This usually occurs within a few hours to a day. Once stabilized, this should represent field capacity for the sensor.

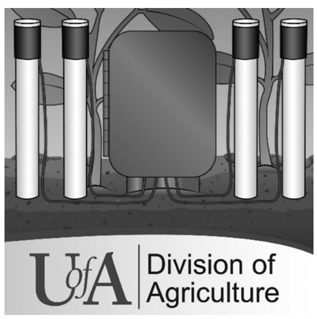

Figure 3-3. Mobile app for soil moisture sensor interpretation.

Key Concepts for Using Soil Moisture Sensors.

There are several key concepts that are common to all soil moisture sensors for scheduling irrigation. First, soil texture determines how much available water holding capacity is available in a soil type. A course textured soil has less water holding capacity than a fine textured soil, such as a silt loam or clay. Silt loams have a higher water holding capacity than clays. When scheduling irrigation, only a percentage of the available water holding capacity is used. Generally, 30-50% of the available water holding capacity is allowed to deplete before irrigating.

Allowable depletions, also referred to as Managed Allowable Depletions or MAD, beyond 50% are considered to accumulate stress in crops. For more conservative irrigation systems such as center pivots, microirrigation, and other situations where irrigation capacity may be more limited, lower allowable depletions such as 30-35% should be used. In surface irrigation systems that can apply 2-3 inches of water at a set, higher allowable depletions are used, such as 40-50%.

Effective rooting depth is the depth at which the irrigator is managing the depletion. In corn the effective rooting depth is about 3 feet. Soil sensor trends should be used to determine effective rooting depth, if water is being depleted at a depth of 30 inches, then this can be used as the effective rooting depth. Effective rooting depths in corn fields in Arkansas range between 18 inches to 36 inches. 30 inches is a good average value to use in most situations.

When determining available water remaining from sensors, an adjustment is necessary to account for irrigation set time. For example, if sensors appear to reach the allowable depletion in four days, and it will take three days to irrigation the field, then irrigation should be commenced after one day.

Arkansas Irrigation Scheduler (AIS) Another tool that is available to irrigators is the Arkansas Irrigation Scheduler.

Soil moisture accounting is used to calculate the soil-water balance in the root zone throughout the growing season. This method is sometimes called checkbook irrigation scheduling because a record is kept on the water that enters and leaves the soil like an account balance is maintained in a checkbook. Daily water use and rainfall amounts are entered into a water balance table. Maximum temperature data can be taken from the weather, newspaper, etc., but the rainfall should be measured with a gauge at each field.

Adding and subtracting these numbers in the table determines the soil moisture deficit. Table 3-4 shows

Table 3-4. Allowable Deficits – Corn		
Predominant Soil	**Flood, Furrow or Border Irrigation (Inches)**	**Pivot Irrigation (Inches)**
Clay	1.75	1.25
Silt Loam w/pan	1.50	1.00
Silt Loam wo/pan	2.00	1.50
Sandy Loam	1.75	1.25
Sandy	1.50	1.00
w/pan – restrictive layer at 10 inches or less below soil surface **wo/pan** – without shallow restrictive layer		

*Assumes 120 day maturity corn, irrigation is triggered at critical depletion with 2" applications, and silt loam soil. Data generated using FAO56 (Smith, 1992; Allen et al., 1998).

the recommended allowable deficits that are used in the AIS.

It uses daily maximum temperatures and rainfall measurements at the field to determine the field's soil moisture deficit. **The program also has the option to predict when irrigation will be needed in the next 10 days if no rainfall occurs**. This offers a real benefit to managing irrigation labor and sharing irrigation water with other crops. The program is web-based and can be accessed at http://www.uaex.uada.edu/irrigation.

Atmometer (ET Gage)

The Atmometer or ET Gage is a modified Bernelli-plate atmometer (ETgage Company, Loveland, Co, etgage.com). They are a cylinder that is filled with distilled water and evaporate water through a ceramic plate, paper membrane wafer, and canvas. There are three common canvases, #54 for alfalfa, #30 grass and a gore-tex in canopy canvas. It is recommended to use the #54 alfalfa reference canvas because it provides better resolution and matches closely the ET predicted from the AIS.

Irrigation Termination

As the crop approaches physiological maturity, a decision on when to stop irrigating has to be made. **The goal is to maintain adequate soil moisture until the corn reaches black layer, which indicates physiological maturity**. This ensures that the kernels can obtain their maximum weight so the crop's full yield potential will be achieved. The decision is best made toward the end of the season by a field determination of the maturity of the crop and the soil moisture status. An initial consideration is how many days it has been since planting. If it has been 90 days since planting and the corn is a 112-day corn, then it may be within 3 weeks of maturity and a field check should be made. Keep in mind, planting date will greatly influence the days from planting to maturity.

At beginning of dent, check the starch line. To determine maturity, break an ear of corn in half, and inspect the kernels in the middle of the ear. Terminate irrigation when the starch line reaches 50% for furrow irrigated fields and 75% for sprinkler systems when there is good soil moisture in the profile (Figure 3-4).

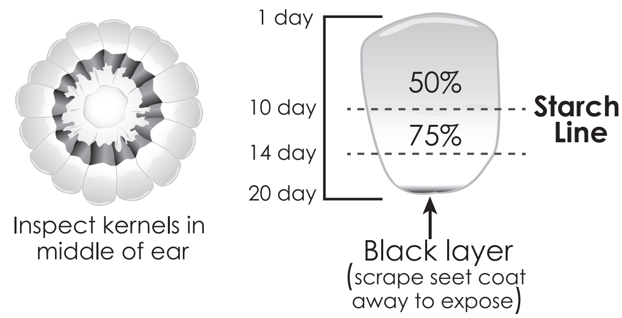

Figure 3-4. Starch line movement for corn

Determining how developed the starch is in the kernel is helpful in making the decision on when to terminate irrigation. The starch begins forming as a line from the top of the kernel and moves toward the tip of the kernel where it is attached to the cob. The progress of the starch line can be checked by taking approximately six (6) representative ears from the field and removing the shucks. The ears can then be broken in half and some of the kernels taken from where the ear was broken. These kernels can be sliced lengthwise so the starch development can be observed. The goal is to determine if there is at least 50 percent starch development inside the kernels sampled. If there is 50 percent starch and good soil moisture exists from a recent surface irrigation or rain, then irrigation can be terminated. However, if the soil is becoming dry at this point, then additional irrigation is needed to assure maximum seed weight and yield.

For center pivot irrigation the starch line should be 75% developed before terminating, since sprinkler systems apply less water than furrow and flood systems.

In the absence of sensors, good soil moisture is more difficult to assess, but an assessment of soil moisture can be done using the "feel method" and by assessing the profile by using a soil probe to 24-36 inches. Probe the profile and assess the moisture by the feel method across the depth of the profile. Good soil moisture is considered if the soil can still form a ball or a ribbon and soil stains the hand. More information on how to determine soil moisture by the feel method can be found in the following publication.

- USDA NRCS, April 1998. Estimating Soil Moisture by Feel and Appearance. Pp.6

Water use for corn to reach maturity by growth stage is provide in Table 3-5. When using sensors the amount of water remaining in the profile can be determined using soil moisture charts, vendor soil sensor information or the factsheet "Predicting the Last Irrigation of the Season using Watermark™ Soil Moisture Sensors.

Good soil moisture determination is much easier to assess with soil moisture sensors. For example for an average soil moisture reading of 50 centibars, at a rooting depth of 30 inches in a silt loam soil, and at 50% allowable depletion (always use 50% allowable depletion when terminating) there is 0.80 inches of available water per foot (Table 3-6). For the 30 inch profile, there is 2.4 inches of available water. If the corn is at R5, only 2.2 inches is required to finish out the crop, so no additional irrigation is required.

Irrigation Methods

The surface and sprinkler irrigation methods used on corn have different characteristics that determine which would be the best for a particular situation. No one method can be labeled as the best – each has its place.

Table 3-5. Crop Water Demand for Corn

Stage	Stage	Days to maturity	Water needed to mature (in)
R4	Dough	34	7.5
R4.7	Beginning dent	24	5
R5	¼ milk line	19	3.7
R5	½ milk line /full dent	13	2.2
R5	¾ milk line	7	1.0
R6	maturity	0	0

Table 3-6. Plant Available Water (inches per foot) for a given Soil Matric Potential or Tension (centibars) at 50% MAD.

Soil Tension (cb)	Sand (1.0"/ft)	Sandy Loam (1.4"/ft)	Silt Loam with Pan (1.58"/ft)	Silt Loam (2.37"/ft)	Clay (1.6"/ft)
0	1.77	1.51	1.01	1.83	1.38
5	1.72	1.51	1.01	1.83	1.36
10	0.74	1.00	1.01	1.65	1.09
15	0.35	0.74	1.01	1.53	0.91
20	0.14	0.58	1.01	1.41	0.78
25	0.02	0.46	0.88	1.29	0.68
30		0.37	0.79	1.19	0.60
35		0.29	0.76	1.14	0.53
40		0.23	0.72	1.00	0.47
45		0.18	0.64	0.89	0.42
50		0.14	0.57	0.80	0.37
55		0.10	0.49	0.71	0.33
60		0.06	0.45	0.63	0.30
70		0.01	0.35	0.50	0.23
80			0.25	0.39	0.18
90			0.21	0.29	0.13
100			0.13	0.22	0.09
120			0.03	0.09	0.02
130				0.03	
140					

Source: Lab and model data of irrigated soils sampled and grouped from Arkansas farms

Furrow Irrigation

Furrow irrigation can be a very effective irrigation method and is the mostly commonly used form of irrigation in Arkansas. One of the biggest requirements for furrow irrigation is that the field must have a positive and continuous row grade. This usually requires precision land grading, which can be rather expensive. However, the grading results in positive field drainage that greatly enhances production. As discussed earlier, the row grade should be in the range of 0.1 to 0.5 percent, and row grades between 0.15 and 0.3 percent are especially desirable for furrow irrigation. The row length to be furrow irrigated is another key consideration. Row lengths of 1,500 feet or less generally water more effectively than longer rows. Row lengths less than 1/4 mile are usually required if sandy soils are to be irrigated effectively.

When row lengths cannot be altered, it may be necessary to control the furrow stream flow by adjusting the number of rows that are irrigated at one time. Experience shows that in most situations it is desirable to get the water to the end of the row in about 12 hours. Water logging soil from excessively long irrigation sets or rain after an irrigation event can lead to yield reduction. This is a concern with the expanded use of irrigation tubing with punched holes for furrow irrigation. The tendency is to punch holes in the tubing as long as water still comes out of them without much concern for how long it will take to water out the row.

The use of Computerized Hole Selection should be used when furrow irrigating corn. Computerized Hole Selection is the use of a computer to size the holes in lay-flat pipe based on row length, flow rate, and pipe crown elevation. Two programs are available a public program, PHAUCET, Pipe Hole And Universal Crown Evaluation Tool and Delta Plastics Pipe Planner (www.pipeplanner.com). CHS has been shown to reduce water use by 20%-50%, saves labor by keeping the pipe within its design burst pressure thus increasing the efficiency of water distribution along the crown or pipeline. CHS plans provide a hole punch plan that proportions the flow rate needed for each furrow. When CHS is properly applied, furrows advance through the field evenly. CHS should be used whenever layflat pipe is used to furrow irrigate corn. More information about CHS can be found on www.uaex.uada.edu/irrigation.

Surge Flow Irrigation

Another improvement to furrow irrigated corn is the use of surge irrigation. Surge irrigation is the alternate wetting and drying of furrows during an irrigation set. Surge irrigation improves down-furrow uniformity also known as the distribution uniformity of water from the top to bottom of the field. More detailed information on surge irrigation is available through a factsheet FSA60 "Surge Irrigation" available at www.uaex.uada.edu/irrigation. Surge irrigation should be used with CHS and soil moisture sensors to improve irrigation on furrow irrigated corn. The factsheet provides guidance on how to set a surge valve for different soil types. Surge irrigation is an oscillating valve that directs water to two irrigate sets a "right" and "left." Valve programs are complex and in the first phase of surge irrigation, water is "advanced" through the field by progressively longer oscillations. Users adjust the advance time to match the advance time observed in the field. Then there is a "soak" phase where the valve oscillates much faster. The soak phase provides the down furrow uniformity improvements, whereas advancing oscillations limit deep percolation in sandy soils. In cracking clay soils it is recommended to irrigate every other furrow and set the advance time to the total irrigation time. In sandy and silt loam soils, the advance should be about half of the total irrigation time and on sealing silt loams, the valve should be adjusted to function mostly in soak mode. In clay soils, the valve should be set so that the total irrigation set time is the same as the advance time, and the number of cycles per time is reduced per Table 3-7.

Table 3-7. Settings for Clay soils for a Surge Irrigation Valve.

Advance Setting (hrs)	Default Cycles/side setting	Custom cycles/side Recommendation
5	4	4-1 (3 total cycles)
10	5	5-2 (3 total cycles)
15	6	6-2 (4 total cycles)
20	6	6-2 (4 total cycles)
30	6	6-2 (4 total cycles)

Source: FSA60, Surge Irrigation Factsheet

The total time to irrigation a field with a surge valve should be ideally less than 24 hours but not more than 40 hours. An ideal set time is 24 hours for surface irrigation. Any irrigation set that is longer than 40 hours could experience water-logging stress. Table 3-8 shows

Table 3-8. Field area in acres that can be irrigated in a 24 hour set time for given application depth and source flow rate.

Flow Rate (gpm)	Application Depth (ac-in/ac)		
	2"	2.5"	3"
500	13	11	9
750	20	16	13
1000	27	21	18
1250	33	27	22
1500	40	32	27
1750	46	37	31
2000	53	42	35
2500	66	53	44

the area of a field that can be irrigated for a given flow rate. For example, for a 1,000 gpm source, and a target application depth of 2.5 ac-in/ac a maximum area of 21 acres can be irrigated within a 24 hour period. Fields should be divided into sets that have reasonable times. Proper division into sets will improve yields, irrigation efficiency, and reduce labor and pumping costs.

Often irrigators attempt to irrigate a larger area than can be irrigated, thus it is necessary to divide a field into smaller sets for effective and efficient irrigation. Use supply lines to divide a field into smaller sets rather than plug holes. For example, one run of tubing would go across the first half of the rows and have holes punched for each middle to be irrigated. A longer run of tubing is then laid behind the shorter tubing. Beginning where the shorter tubing ends, holes are punched in the longer tubing for the middles irrigated across the remainder of the field. This allows row sets to be changed by unhooking one run of tubing from the irrigation well or riser and hooking up the other run. If more than two sets are required for a field, then alternate rows may be irrigated to avoid the laying of additional tubing. It is also possible to get multi-valved fittings that can accommodate three or more sets and reduce the amount of tubing needed to avoid the plugging and unplugging of holes. For surge irrigation two sets are put together where their total is not more than 24-40 hours. Where there are four sets, they can all be brought to the riser and one surge valve used for both irrigations sets. For a normal 24 hour set that was designed without surge, it will be necessary to divide the 24 hour set into two 12 hour sets to result in a 24 hour surge irrigation set.

Furrow irrigation requires a water supply of at least 10 gpm per irrigated acre, and more capacity is desirable if available. At 10 gpm per acre, about five days should be expected to complete an irrigation. Practices like waiting until morning to change sets when rows water out at night can add significantly to the time, making it difficult to finish the field before it is time to begin the next irrigation. A well-defined furrow is needed to carry the irrigation water. Planting on a good bed is the most desirable option for having a good water furrow. If a bed is not used, then it is necessary to cultivate with a furrow plow that moves enough soil from the middle of the rows so that a good furrow is created. Some producers prefer to water alternate middles under certain conditions. Watering alternate middles can result in getting across the field quicker and not leaving the soil as saturated as it might be if every middle were irrigated. In cracking clay soils this is recommended. Mixed results are common with silt loams and sands. If rain comes soon after the irrigation, it is possible for it to soak into the soil rather than run off or collect and stand in low spots. Producer preference and experience, along with the crop and field condition, will deter mine whether it is best to water every middle or alternate middles. Alternate middle irrigation will usually result in having to come back with the next irrigation somewhat sooner than when every row is watered.

Furrow irrigation by necessity requires that there be some amount of tail water runoff from the ends of the rows. All the middles will not water out at the same rate, especially those that are wheel- track middles. Also, cracking soils can make furrow irrigation management more challenging.

Using CHS, surge irrigation, and soil moisture sensors together has resulted in a 27% reduction in water use in paired field county demonstration comparisons, with no yield penalty. Use of these tools can reduce the number of irrigations by half.

Center Pivot Irrigation

Center pivots offer the ability to irrigate fields that have surface slopes that make it impossible or impractical to irrigate with surface methods. They also offer more water management options than surface irrigation. **The need for good surface drainage still exists with pivot irrigation and should not be overlooked.**

Pivots are best suited for large square-, rectangular- or circular-shaped fields free of obstacles such as trees, fences, roads, power poles, etc. Field ditches are also a concern if the pivot towers must cross them. Pivots can cover a range of acreage depending on the allowable length, but the common 1/4-mile, full circle system will cover approximately 130 acres of a 160-acre square field. **It is possible to tow a pivot from one field to another, but it is usually best for a system not to be towed between more than two points during the season.**

Pivots provide the ability to control the irrigation amount applied by adjusting the system's speed. This gives the operator advantages for activating chemicals, watering up a crop and watering small plants. It is also possible to apply liquid fertilizer and certain pesticides through the system. This is called chemigation, and it can be especially applicable to corn for sidedress or late- season applications of fertilizer. **Any chemicals that are to be applied through the system must be**

specifically labeled for chemigation. The label will give specific application requirements and recommendations if a chemical is approved for chemigation application. Any pivot system used for chemigation must have some specific equipment and safety devices installed. Information on equipment requirements and chemigation is available through most center pivot dealers or companies. A chemigation system should have a vacuum relief valve, check valve, low pressure drain and an inspection port. Additionally, there must be an interlock between the injection pump and irrigation pump. Great care must be taken to ensure chemicals and fertilizers cannot be siphoned or pumped into water sources.

It is recommended that a pivot have a water supply of at least 5 gpm per acre that is irrigated. At that rate, nearly four days are required to apply a 1-inch irrigation. It is better to have a design capacity of 7-10 gpm per acre. However, at this capacity, it is more likely that over irrigation can be a result, so use of a scheduling system is prudent. A water supply less than 5 gpm/ac leaves no room for break down time without the risk of getting behind in meeting the crop water needs.

The capacity for a towable system should be greater to account for the added time needed to move the system. It is recommended that pivot irrigation be applied early enough to avoid the deeper soil moisture being extracted early in the season. If the deeper moisture is used early in the season, it becomes difficult for a pivot to keep up with the water demand unless rainfall replenishes the deep moisture. A pivot irrigation will typically influence the soil water between 6 and 12 inches. Less often can water soak past 12 inches with irrigation, however it more common with rainfall. The goal should be to save the deeper subsoil moisture for when corn is approaching maturity. A steady trend of subsoil extraction is preferred over maintaining a moist subsoil and extracting the subsoil moisture earlier in the season. Subsoil moisture levels that do not change indicate deep percolation and leaching may be occurring and a rapid extraction of subsoil moisture indicates inadequate early season irrigation. Irrigation scheduling with a center pivot is different than with furrow and border irrigation. The goal in center pivot irrigation should be to add what is lost during the week. This can be done with sensors or ET based systems. It is recommended to set and calibrate a pivot to a known application depth, such as 1 inch. This is more reliable than adjusting the percent run time, unless the operator has confirmed the application depths provided in the pivot chart.

Center Pivot Scheduling using and Atmometer or ET based system

Consistent and profitable corn production in Arkansas is difficult without irrigation. Once irrigation is in place, the irrigation operating cost for each irrigation is typically \$3 to \$6.50 per acre. This cost is easily justified by the yield increase that can result from the irrigation. The maximum profit usually results when the maximum yield is obtained, so the irrigation goal is to obtain the maximum yield by preventing crop moisture stress. **Irrigation is not a cure-all. Maximum yield and profit will be achieved only when irrigation is coupled with other production practices that establish profitable yield potentials.**

The following procedure can be used with an Atmometer using the #54 canvas cover to weekly schedule pivot turns. Since pivots usually take 2-3 days to make a turn, this is used to determine when only one turn would be needed in a week versus the normal two for example. An ET chart is available at www.uaex.edu/irrigation for corn and soybeans using this methodology. The basic concept is this, first determine the amount of crop water demand using the Atmometer and crop coefficients. Next match number of turns per week to the crops water demand using the pivot application depth, accounting for irrigation efficiency.

Step 1. Determine daily ALFALFA Reference ET from a weather station or an Atmometer or ET gage. For an Atmometer, determine the difference in reading over time. Read at same time of day or adjust accordingly.

> *Example:* Initial reading = 1.0” on Day 1 Reading at day 4 = 1.9” on Day 4 Four day ET,: 1.9” - 1” = 0.9” / 4 days = 0.23”/day

Step 2. Determine the weekly ET, Multiple daily ET by 7 days.

> *Example:* 0.23”/day x 7 days = 1.61”

Step 3. Determine Crop Demand, net irrigation required. Adjust for Crop Coefficient, net = ET x Kc, Use Table 3-9.

> *Example:* corn at V12, Kc = 0.72 from Table 1, 1.61” x 0.72 = 1.16”. This is net weekly application required.

Table 3-9. Crop Coefficients for Corn (Alfalfa Reference).	
Growth Stage	**Kc**
V2	0.12
V4	0.2
V6	0.37
V8	0.53
V12	0.72
V14	0.91
V16	1.04
VT Tasseling	1.06
R1 Silking	1.06
R2 Blister	1.06
R3 Milking	1.06
R4 Dough	1.06
R5 Begin Dent	1.04
R5 Dent ½ milk	0.21

Step 4. Adjust for Irrigation Efficiency (gross application needed). Use Table 3-10, determine efficiency, gross = net/IE.

Example: 1.16" / 0.80 (for average pivot nozzles) = 1.45". This is the gross application required for the week.

Table 3-10. Irrigation Efficiencies for Center Pivots	
Pivot Condition	**Irrigation**
Rotators or sprays in good condition	0.85
Average	0.75 - 0.8
Below Average condition	0.7

Step 5. Determine run interval. If actual application is 0.9" by chart or by calibrating with rain gages, two turns will result in 1.8" applied. 1.8" - 1.45" = 0.34" excess, add this amount to next weeks water balance. So if next week gross required is 1.6" (V16) and 0.2" rain occurred, then 1.6" - 0.34" from previous week - 0.2" rain = 1.06" required in following week 1.06" - 0.9" = 0.16" excess needed in following week.

Most pivots are equipped with low-pressure sprinkler packages, and many are mounted on drops that release the water closer to the soil surface. This is desirable as long as the system application rate is matched to the soil and field characteristics so excessive runoff is avoided. If a field has a rolling surface and a soil that tends to crust or seal over, this should be taken into account in the sprinkler package selection. Minimum tillage that leaves crop residue on the surface can help reduce runoff problems. It might also be possible to put in narrow width (1 inch or less) slots at a depth of about 8 inches in some of the middles. This can be done with vertical tillage shanks in order to give the water a path for soaking in rather than running off a sealed or crusted-over soil surface. Another potential solution for crusting and runoff is the use of cover crop and the residue remaining after termination. Many growers are experimenting with cover crops and no-till or reduced tillage, and this is an alternative to tillage to reduce compaction and runoff problems.

One of the biggest advantages of pivot irrigation is the limited labor required for operating the system. The biggest challenge with center pivots is the initial cost. However, they offer some advantages that can justify the initial cost, especially when surface irrigation is not possible and the cost is spread over an expected service life of at least 20 years.

When considering the different irrigation methods, it is important to remember that any method that is well planned and is properly installed, operated and maintained can give the results desired. Every method requires time to irrigate the whole field, so it is very important that irrigation be started early enough that no part of the field suffers moisture stress.

Arkansas Situation

Consistent and profitable corn production in Arkansas is difficult without irrigation. Once irrigation is in place, the irrigation operating cost for each irrigation is typically $1.50 to $11.60 per acre. This cost is easily justified by the yield increase that can result from the irrigation. The maximum profit usually results when the maximum yield is obtained, so the irrigation goal is to obtain the maximum yield by preventing crop moisture stress. Maximum yield and profit will be achieved only when irrigation is coupled with other production practices that establish profitable yield potentials.

A study was conducted on 18 paired fields between 2013 and 2017 in Arkansas and Mississippi corn fields comparing fields that used IWM versus arbitrary-based farmer control irrigation methods. Using Irrigation Water Management (IWM) practices, computerized hole selection, surge irrigation, and soil moisture monitoring was found to increase corn grain yield by 6.5 bushels per acre while reducing water use by 39.5%. This improved yield recovers the cost of the surge valve and sensors through energy savings resulting from the reduced pumping time. The total net returns for IWM are significantly higher (P=0.01) by $25 to $39 per acre over fields without IWM, irrespective of the depth to groundwater or diesel prices (Spencer, 2019). In addition to the yield stability irrigation provides for corn production in Arkansas, added profit over costs is achievable through well managed irrigation.

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