Subsurface Drip Irrigation for Corn Production and Research
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Summary

- Subsurface drip irrigation (SDI), first commercialized in the 1960s, now accounts for over 50% of the irrigation of horticultural and specialty crops.
- SDI is becoming increasingly popular in some row crops such as cotton in California and west Texas where water supplies are under increasing pressure. In irrigated corn, subsurface drip irrigation has yet to become as popular.
- Recent water use restrictions and drought and fertilizer runoff concerns have renewed interest in SDI as a more efficient and precise means of water and fertilizer delivery.
- One distinct advantage of SDI is its ability to provide reliable irrigation where full circle center pivot sprinkler systems are not practical, such as corners and irregular fields.
- Precision water delivery via SDI has allowed Pioneer researchers to improve selection and characterization of drought-tolerant germplasm.
- This has resulted in development of Pioneer’s Optimum® AQUAmax™ corn products, which yielded 7.1% more under drought and 3.4% more in favorable environments (on average) vs. competitors in 2011c.
- SDI is also utilized to accurately deliver nitrogen rates and timings in characterization and breeding of corn for improved nitrogen-use efficiency.
- As water regulations and drought limit water supplies, SDI systems offer an ideal method for on-farm comparisons of hybrids under restricted water regimes.

Introduction

Modern subsurface drip irrigation (SDI) systems are designed to conserve water and nutrients. This is accomplished by delivering water directly and slowly into the root zone through a network of buried laterally spaced polyethylene drip lines with emitters (Lamm and Camp, 2007). Drip lines are typically buried 8 to 15 inches below the surface and spaced approximately 60 inches apart. The exact placement depends on soils, climate and row management practices. SDI systems essentially eliminate surface soil water evaporation and runoff. When coupled with effective irrigation management principles, SDI provides the opportunity to supply enhanced water and fertilizer amounts directly to the root zone; thus, essentially “spoon feeding” the crop. This minimizes or eliminates the movement of water and nutrients below the root zone. When properly managed, application losses (wind drift, soil evaporation and deep percolation) are negligible or considerably lower for SDI systems than for traditional surface irrigation systems (Payero et al, 2005).

Use of drip irrigation has earned high adoption rates in horticultural and specialty crops by increasing yields as well as efficiency of water and fertilizer applications. However, in irrigated corn, SDI has yet to become as popular, likely because of higher initial installation costs for SDI systems. Adequate rainfall or plentiful irrigation water delivered mainly via center pivot sprinkler irrigation systems has so far provided for high and increasing yields throughout much of the U.S. Corn Belt. However, in recent years, water districts and government agencies have imposed more stringent water restrictions for surface and groundwater resources such as the Ogallala aquifer. Therefore, it is increasingly important to understand which irrigation technologies are most water efficient and which corn hybrids will consistently yield the most under restricted irrigation.

Similarly, as concerns about fertilizer (especially nitrogen) runoff and leaching into water systems increases, it is worthwhile to investigate more precise and controllable delivery methods for fertilizers in Midwest crop production. Because of these resource issues, and concerns about drought as the leading cause of yield loss in U.S. corn production, interest in SDI as a more efficient, highly manageable means of water and fertilizer delivery is likely to increase.

This Crop Insights reviews the history of drip irrigation development, discusses the comparative features, benefits and economics of SDI for corn production and details how SDI is being used in research to characterize and create corn hybrids with improved drought tolerance and nitrogen-use efficiency.
History of Drip Irrigation

Early forms of drip irrigation can be traced back to ancient times where clay pots filled with water were buried in the ground, allowing the water to gradually leak out and into the root zone of nearby vegetation. In the mid-1800s, more sophisticated drip irrigation systems were developed in central Asia using various types of clay pipe for both irrigation and drainage. In the U.S., a researcher at Colorado State University in 1913 documented the application of subsurface water directly to the root zone of plants (House, 1918).

The ability to mold plastics became more widespread and cost effective after WWII. This helped pave the way for improvements in the manufacturing of drip irrigation components, including early versions of emitters, making drip irrigation more common throughout the U.S. and Europe. In Israel, Simcha Blass & Yeshayahu Blass formed a company called Netafim, improved emitter design, and created a method for water to flow with less potential for clogging. Netafim then patented the first Israeli drip irrigation emitter. This development helped the technology of drip irrigation rapidly expand to Australia, North America, and South America in the late 1960s.

More recently, use of SDI has become more popular for row crop irrigation, especially in areas where water supplies are limited or recycled water is used for irrigation. Thus, modern drip irrigation is proving to be one of the world's most valued innovations in agriculture since the invention of the impact sprinkler in the 1930s, which replaced flood irrigation.

Uses of SDI in Corn Production

In much of the Great Plains, the rate of new irrigation development is slow or nonexistent. Center pivot sprinkler irrigation systems have continued to be the dominant method for irrigating in this region, occupying over 90% of irrigated acres. However, use of SDI on row crops in the U.S. increased from around 400,000 to 640,000 acres over a six-year period (2003 to 2008), representing a 59% increase (USDA-NASS, 2009). This demonstrates that adoption of SDI for row crop production has increased significantly in recent years.

SDI versus Center Pivot (CP) Irrigation System

Higher installation costs of SDI compared to CP systems have been listed as one of the main impediments to greater adoption of SDI systems (Payero, 2005). However, as water resources become more limiting and expensive, the water-saving nature of SDI may offset its higher initial cost. Kansas State University Research and Extension personnel (Lamm et al., 2012) have developed a free Microsoft Excel spreadsheet template for making economic comparisons of CP and SDI, which can be downloaded at: [http://www.ksre.ksu.edu/sdi/](http://www.ksre.ksu.edu/sdi/). Input factors for the calculator include field size and shape, irrigation system costs, system life, production costs for each system, etc. The spreadsheet also provides sensitivity analysis for key factors.

Some key observations from using the calculator:
- Baseline analysis assumes 25% water saving for an SDI system vs. CP system
- CP systems have an economic advantage over SDI for large fields
- SDI systems are favored over CP for small and irregular-shaped fields
- Higher corn yields and corn prices favor SDI economics
- Increasing longevity of SDI is the most important factor necessary for SDI to become economically competitive with CP systems

Use of SDI in Pioneer Optimum® AQUAmax™ Drought Research

Pioneer Optimum AQUAmax Drought Research:

Drought stress is the leading cause of yield loss in the U.S. at about $3 billion annually (Pioneer and CSA news). For this reason, Pioneer has conducted extensive drought breeding research since the 1950s to increase corn hybrid drought tolerance. These efforts have dramatically increased water-use efficiency of hybrids over this period (Figure 1).

In 2011, Pioneer released a line of Optimum AQUAmax corn products which capitalize on many of the latest advances in molecular selection of native corn traits. Optimum AQUAmax products produced 7.1% higher yields under drought and 3.4% higher yields in favorable conditions vs. competitors (on average, in almost 8,000 on farm comparisons in 2011)². One key to selecting and-breeding drought tolerant hybrids has been the use of SDI to create a network of managed drought stress testing environments in arid locations. This extensive network includes Woodland, CA; Garden City, KS; LaSalle, CO; York, NE; Manhattan, KS;
Plainview, TX; and Viluco, Chile. Using the precise water delivery of SDI at these facilities allows Pioneer breeders to conduct thousands of head-to-head comparisons under drought-stress conditions.

By varying the amount and timing of water delivered through the drip systems, breeders are able to uniformly “load” the soil profile with moisture. This allows evaluation of germplasm across the entire range of soil moisture conditions from severely stressed to well-watered at multiple crop stages. SDI enables researchers to accurately induce different levels of stress at the two most important crop stages to evaluate for drought stress: 1) pollination, when the crop’s demands for water are highest for silk elongation, pollen germination and pollen tube growth; and 2) grain filling, when water stress can result in kernel abortion and reduced kernel weight.

The precision of SDI is critical to accurately and efficiently select the most drought tolerant and high yielding corn lines. Therefore, researchers can simultaneously increase yield under both drought and well-watered conditions. The next phase of drought research to select for non-native genetic traits is underway and depends largely on the precision water delivery of SDI for accurate field evaluation of each new candidate trait.

**Pioneer Nitrogen-use Efficiency Research:**

Similar to drought research, SDI allows Pioneer researchers to deliver precisely metered levels of N fertilizer at any crop stage to create accurate comparisons of corn germplasm for N-use efficiency. As a side benefit of this effort, Pioneer researchers are investigating the physiological response of corn to novel N fertilizer timings and amounts as a means of increasing yields. For example, in preliminary studies Pioneer researchers have found that delivering pulses of N via the drip system to corn in a two week window around pollination can significantly increase yield. For example, use of a strategically timed (at tasseling and silking) hand application of 100 lbs/acre of N by David Hula was considered to be instrumental in winning the 2011 NCGA corn yield contest with 429 bushels/acre. David Hula and Pioneer researchers estimate that this strategy added 40 to 50 bu/acre to the yield of this contest winning field (Jeff Schussler and David Hula, personal communication). Although these results need further corroboration, the use of SDI is one means of applying such treatments.

**Using SDI for On Farm Evaluation of Drought resistant or Nitrogen Efficient Hybrids**

With the release of Optimum® AQUAmax™ drought-tolerant corn hybrids, SDI systems offer an effective means for on-farm hybrid evaluation under restricted water regimes. The same system could also be used to evaluate on-farm performance of hybrids designed for increased nitrogen-use efficiency in future years. The following experimental design (Figure 2) is an example of how a grower could evaluate Optimum AQUAmax hybrid performance compared to other hybrids under restricted water scenarios.

As water districts and government agencies impose water restrictions for the Ogallala aquifer and other regions, it is increasingly important to understand which irrigation technologies are most water efficient and which corn hybrids will consistently yield the most under restricted irrigation.
have experience with SDI systems. The Kansas State University web site (http://www.kstre.ksu.edu/sdi/) is another good source of information if considering installing an SDI system.

Conclusions

In summary, SDI is considerably more efficient in applying water and crop nutrients than other traditional irrigation systems like center pivot (CP). Even though SDI is more efficient, it has been mainly used on higher value horticultural crops due to its greater initial investment costs. However, as water resources become scarcer and more expensive, use of SDI in row crop production is increasing. Currently, SDI systems are favored over CP for small and irregular field shapes, such as corners of CP-irrigated fields.

The use of SDI by Pioneer researchers to create a network of managed drought stress testing environments in arid locations has also been instrumental in the development of Optimum AQUAmax drought-tolerant hybrids. The more precise control of water and fertilizer that SDI affords is critical in hybrid research and is gaining use in seed production. Given pressure to improve water and fertilizer use as well as potential savings and benefits, increased use of SDI in commercial corn production is expected.

Growers considering the installation of SDI system are encouraged to seek as much information as possible to make profitable decisions. If available, consult local growers who have experience with SDI systems. The Kansas State University web site (http://www.kstre.ksu.edu/sdi/) is another good source of information if considering installing an SDI system.

References


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Images courtesy of Netafim and Kansas State University.

In 2011, the initial commercial class of Optimum AQUAmax hybrids was grown in on-farm comparisons across the US against commercially available competitor hybrids selected by the grower in 680 water-limited environments with a win ratio of 64%; and 7,258 comparisons under more favorable growing conditions with a win ratio of 67%. Water-limited environments are those in which the water supply/demand ratio during flowering or grain fill was less than 0.66 on a 0-1 scale (1=adequate moisture as determined by Pioneer) using Pioneer’s proprietary EnClass<sup>a</sup> system and in which the average yield of the commercially available hybrids was less than 150 bu/acre. Moisture levels were measured at the nearest weather station. More favorable growing conditions are locations where yield levels were at or above 180 bu/acre on average, regardless of moisture levels. Product performance in water-limited environments is variable and depends on many factors such as the severity and timing of moisture deficiency, heat stress, soil type, management practices and environmental stress as well as disease and pest pressures. All hybrids may exhibit reduced yield under water and heat stress. Individual results may vary.

PIONEER<sup>b</sup> brand products are provided subject to the terms and conditions of purchase which are part of the labeling and purchase documents.

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<sup>b</sup> Images courtesy of Netafim and Kansas State University.