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POTENTIAL FOR INTENSIFICATION OF MAIZE PRODUCTION WITH SDI

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SUMMARY

In 2017, a study was conducted at the KSU Northwest Research-Extension Center in Colby, Kansas to evaluate the potential for intensification of field corn production with subsurface drip irrigation. Experimental factors were three irrigation levels (115, 100, or 85% of ET-rain replacement), two high-yielding corn hybrids (Pioneer 1151 or Pioneer 1197) and three elevated plant densities (42,000, 38,000, or 34,000 plants/acre). Corn yields were not affected by irrigation level and significantly greater crop water productivity (CWP) was obtained by the lower 85% ET-rain irrigation treatment. There were significant differences between hybrids with Pioneer 1197 averaging nearly 9% more grain yield, primarily due to a greater number of kernels/ear. Increasing plant density from 34,000 to 38,000 or 42,000 plants/acres increased grain yield by 4% (10 bushels/acre). Seasonal profile soil water was relatively stable across irrigation treatments and plant densities further indicating that the 85% ET-Rain irrigation treatment was sufficient for this corn production intensification study. These results are part of a mult-year study. Unfortunately, the 2018 crop was lost due to wind and hail damage. More results are necessary before firm conclusions should be drawn.

INTRODUCTION

Crop production intensification is a key factor for addressing one of the greatest challenges of this century: feeding 9.5 billion people by the year 2050. Inherent in this challenge are the limitations of arable land as well as a shortage of fresh water sources. Ecologically, crop intensification can protect marginal lands from further development and save water resources. Intensification on a smaller land area also has potential to reduce crop production and crop protection inputs. These include seed, fertilizer, herbicides, pesticides, crop scouting, crop insurance, harvesting costs and any other input cost that has a fixed cost per land area basis.

Crop water productivity (CWP, also known as water use efficiency, WUE) is defined as the yield divided by the total water use:

$$CWP = \frac{Crop\ Yield}{Total\ Wate\ Use} \qquad \text{Eq 1.}$$

Thus, it can be easily recognized that either the numerator can be increased, or the denominator can be decreased to increase CWP. Often strategies to increase CWP concentrate on the denominator such as using deficit irrigation to reduce water withdrawals. Implicit with these strategies is the desire to not greatly reduce farm profitability by negatively impacting crop yields to a large extent. However, a traditional definition of deficit irrigation is a level of irrigation anticipated to reduce crop evapotranspiration (ETc) to less than the full potential amount. Since crop yield and ETc are typically linearly related, a reduction in ETc often means a reduction in crop yield. There are limitations to using the denominator to increase CWP, since the overall reason irrigation is practiced is to increase farm profitability. Actually, it can be shown that appropriate levels of irrigation can actually increase CWP (Figure 1).

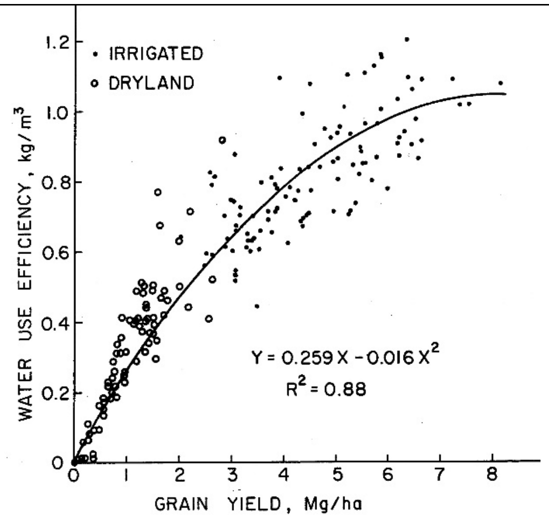

Figure 1. Wise use of irrigation can increase CWP, here expressed as WUE. (Data after Evett et al. 2014, using data from Musick et al., 1994).

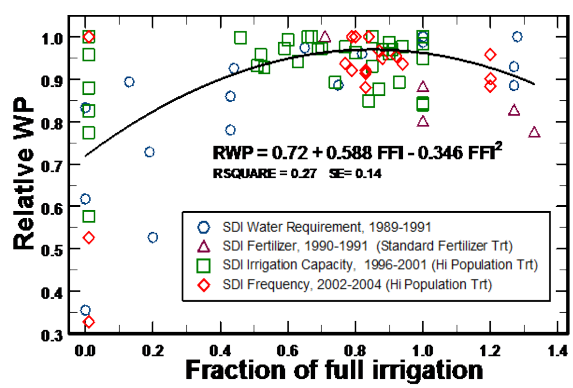

Figure 2. Crop water productivity maximized at about 80% of full irrigation in four different SDI studies at Colby, Kansas from 1989 through 2004. Graph summarized by Lamm and Rogers, 2014.

Subsurface drip irrigation (SDI) has great potential to optimize crop production at a greater level while efficiently using water. Earlier studies have indicated CWP could be maximized with SDI at about 80 percent of full irrigation for corn and still result in high crop yields (Figure 2 and Lamm and Rogers, 2014). Although the corn yields in these earlier studies were high (200-250 bushels/acre), with additional intensification greater yields are anticipated (consistently greater than 280 bushels/acre). These greater yields are not unrealistic, as SDI corn yields as high as 304 bushels/acre were obtained in a research study in Kansas in 1998 (Figure 3). Consistently increasing yields above 280 bushels/acre will require optimal fertilization. SDI allows for timely in-season fertigation (application through the subsurface driplines to the center of the root zone).

Plant density of modern corn hybrids can be increased to reasonably high levels without plant barrenness due to advances in genetics. In SDI studies at Colby, Kansas there appeared to be little yield penalty with greater plant density even when irrigation and precipitation was greatly limited (Figure 3). It is thought that even small amounts of water when applied daily with SDI can help alleviate some of the water stresses that would occur with other types of more infrequent irrigation (e.g., surface or sprinkler irrigation).

Plant hybrids also play a major role in high yielding systems. Pioneer 1151 has been shown to have a large kernel mass (≈380 mg) that is surprisingly stable across a wide range of irrigation regimes (Lamm, 2016). Pioneer 1197 is also a great hybrid which has been documented as a hybrid-of-choice in many high yield contests conducted by producers (Jeschke, 2017).

It is already known that intensification can have positive results. Comparing crop yields for the period pre- and post-introduction of commercial fertilizers is a prime example. Further investigations of increasing CWP with crop intensification are warranted. These efforts will concentrate on optimizing additional inputs: the focus of such efforts will be to increase the numerator of the CWP equation (crop yield).

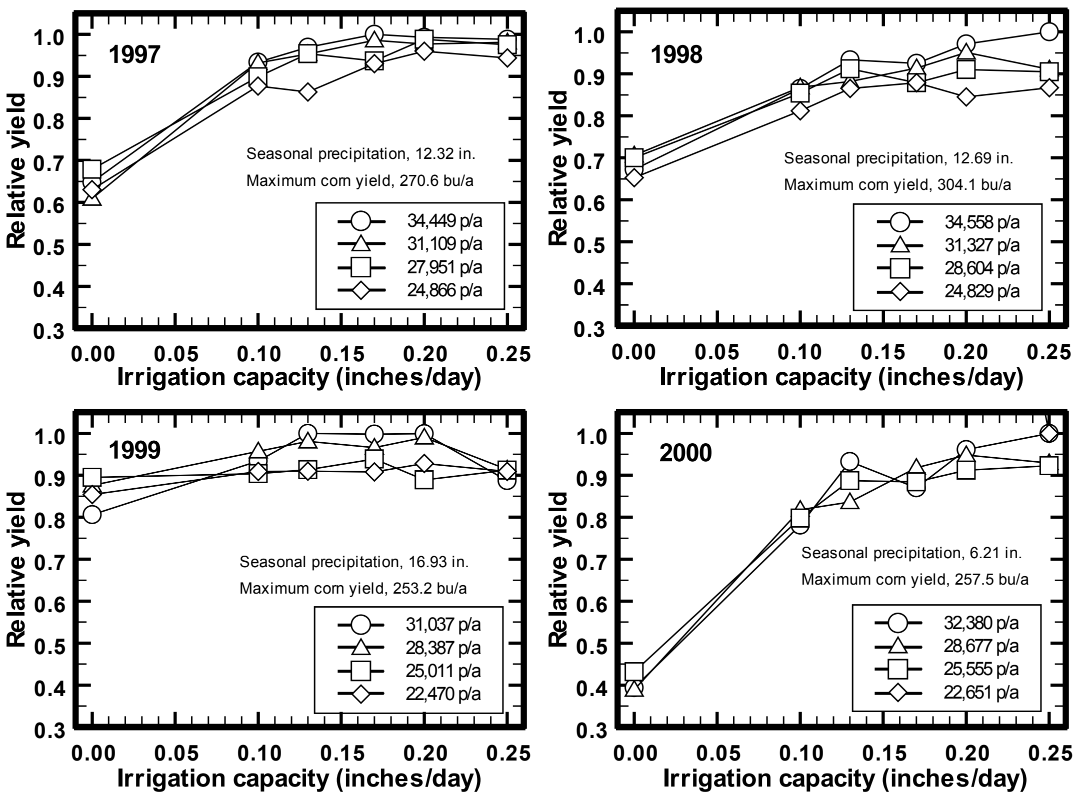

Figure 3. Maximum SDI corn grain yields ranging from 253.2 to 304.1 bushels/acre with modest irrigation capacities and in-season precipitation ranging from 6.21 to 16.93 inches at Colby, Kansas. Average in-season precipitation is approximately 12.3 inches. ***It can be noted that the greatest yield in most years was at the greatest plant density and that the maximum yield (304 bushels/acre) in 1998 still appears to be increasing.***

BRIEF DESCRIPTION OF PROCEDURES

A study was initiated in 2017 at the KSU Northwest Research-Extension Center at Colby Kansas to evaluate intensification of corn production with SDI. The study was also conducted in 2018 but the crop area was abandoned due to heavily damage from wind and hail on June 30. This report will only discuss the 2017 results. The site has a deep silt loam soil and a semi-arid climate. Experimental factors were limited to three irrigation levels, (115, 100, and 85% of ET-Rain), three elevated plant seeding densities (34,000, 38,000 and 42,000 seeds/acre) and two high yielding corn hybrids (Pioneer 1151 and 1197). Fertilization was not included as a study variable in this study due to space limitations at the site, but was fixed at an advanced level with in-season applications of nitrogen, phosphorus and potassium as well as micronutrients. This fertilization scheme was selected from one of the more promising schemes currently being evaluated with SDI at the Center (results are unpublished at this time).

The SDI system was installed in 2016 at a depth of 16 inches with a dripline spacing of 5 ft. The emitter spacing for this system is 12 inches and the emitter flowrate is 0.15 gallons/hour. The SDI application rate is 0.05 inches/hour. Since this system is subsurface, not wetting the soil surface, the irrigation frequency does not affect evaporative losses, so the SDI frequency was more frequent daily applications as governed by the irrigation regimes.

Soil water was measured in the complete root zone (0-8 ft) with a neutron probe periodically throughout the season to help quantify periods of water stress and to determine crop water use. Weather data was measured using an automated KSU weather station approximately 1500 ft. from the study site. Corn grain yield was determined by hand harvesting a representative sample at physiological maturity which enabled the determination of all corn yield components, (grain yield, plant density, ears/plant, kernels/ear, and kernel mass) as well as the important intermediate yield component, kernels/area. Data analyses included correlation of corn yield and yield components, seasonal water use, irrigation as affected by irrigation regime, corn hybrid and plant density.

RESULTS AND DISCUSSION

Weather Conditions and Irrigation Requirements

The 2017 season started out very wet (Figure 4) but ended with cropping season precipitation just slightly above normal. Calculated well-watered corn evapotranspiration (ET) was just slightly below normal. Planting was slightly delayed by wet conditions until May 9 and the crop emerged approximately 5 days late on May 20. Installation of soil water measurement tubes was delayed by wet weather and the initial soil water readings were on June 6. Relatively mild summer weather with timely rainfall and an extended grain-filling period resulted in an exceptionally good corn growing season. Irrigation amounts were 12.00, 14.50 and 16.75 inches for the 85, 100 and 115% ET - Rain irrigation treatments, respectively.

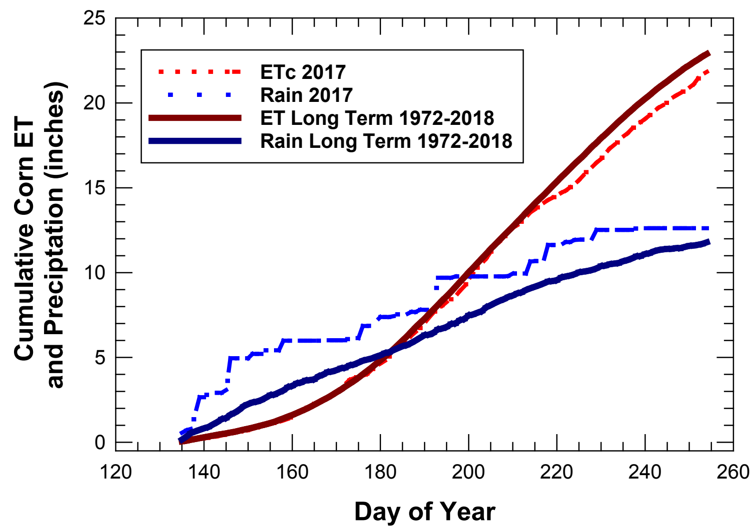

Figure 4. Cumulative calculated well-watered corn evapotranspiration (upper lines) and measured precipitation (lower lines) at Colby, Kansas for May 15 through September 11, 2017 as compared to the long term (1972—2018) average values.

Corn Yields, Yield Components, Water Use, and CWP

Corn yields were excellent in 2017 with the mean of 4 replications ranging from 269 to 314 bushels/acre for the various treatment combinations.

Yields were not affected by irrigation level (Table 1), which corresponded to earlier findings that SDI levels approximating 75 to 80 percent of full irrigation will maximize yields (Lamm and Rogers, 2014 and also illustrated in Figure 2). Irrigation increased crop water use, but this only reflects the higher irrigation amounts which were likely reflected in increased deep percolation. This is further emphasized by the statistically significantly greater crop water productivity (CWP) at the irrigation level designed to match 85 percent of ETc minus precipitation. The fact that greater irrigation levels were not necessary with crop intensification is important in that the denominator of CWP was not increased to result in greater corn yields.

There also was a strong hybrid effect on yield: Pioneer 1197 exceeded Pioneer 1151 by 24 bushels/acre, emphasizing that hybrid selection remains an important factor in intensively managed corn. This yield increase for Pioneer 1197 was caused primarily by greater number of kernels per ear. Pioneer 1197 also had higher crop water productivity (CWP) than Pioneer 1151, but crop water use was slightly greater with Pioneer 1197.

A plant density of 38,000 or 42,000 plants/acre resulted in significantly greater yield than 34,000 plants/acre, but crop water use was not affected at approximately 27.26 inches. Although the lower plant density had greater number of kernels per ear, this value was not able to compensate for the lower plant density. This reflects a growing understanding that maximizing irrigated corn yields often requires maximizing the intermediate yield component of kernels/area (i.e., plant density multiplied by ears per plant multiplied by kernels per ear).

Table 1. Corn yield and water use parameters in an SDI study with intensive management at the KSU-NWREC, Colby, Kansas in 2017.							
Main Effect	**Grain yield (bu/a)**	**Plant Density (p/acre)**	**Ears /Plant**	**Kernels /Ear**	**Kernel Mass (mg)**	**Crop Water Use (inches)**	**Crop Water Productivity (lb/a-in)**
Effect of Irrigation Level							
Irr 1, 115% ETc *(16.75 inches)*	293	37679	1.02	587	33.3	**29.19 A**	**563 C**
Irr 2, 100% ETc *(14.50 inches)*	292	37716	1.02	586	33.3	**27.10 B**	**605 B**
Irr 3, 85% ETc *(12.00 inches)*	289	37752	1.01	580	33.6	**25.50 C**	**638 A**
Effect of Hybrid							
Hybrid 1, Pioneer 1151	**280 B**	37873	1.01	**556 B**	33.7	**26.68 B**	**590 B**
Hybrid 2, Pioneer 1197	**304 A**	37558	1.02	**612 A**	33.1	**27.84 A**	**614 A**
Effect of Plant Density							
Plant Density 1, 42K p/a	**296 A**	**41600 A**	0.99	**552 C**	33.0	27.35	607
Plant Density 2, 38K p/a	**295 A**	**37788 B**	1.02	**587 B**	33.3	27.30	608
Plant Density 3, 34K p/a	**285 B**	**33759 C**	1.03	**614 A**	34.0	27.14	591
Data for a main effect within a column followed by different letters are significantly different at P=0.05 level.							

Seasonal Available Soil Water Change as Affected by Irrigation Level and Plant Density

As an additional illustration of the adequacy of the 85% ET-Rain irrigation treatment, a time series of available soil water (ASW) for the three irrigation treatments as affected by the highest and lowest plant densities was graphed (Figure 5). There was less than 0.47, 0.96, and 1.13 inches differences in the ASW values for a given profile depth, 2, 4, or 8 ft, respectively, on a given date as affected by the three irrigation levels or the highest and lowest plant density. Seasonal ASW for the three profile depths, 2, 4 and 8 ft all had narrow ranges, 3.73 to 4.84 inches/2 ft, 7.07 to 9.05 inches/4 ft, and 12.99 to 16.27 inches/8 ft, respectively. The small differences and the narrow range of values indicate that there was very little water stress experienced by the corn plants. The larger range of ASW values for the 8 ft depth suggests some of the applied water was moving downward for the higher irrigation treatments.

CONCLUSIONS

In this first year (2017) of a multi-year study, corn grain yield was unaffected by irrigation levels ranging from 85 to 115% of ET-Rain replacement. Significantly greater CWP was obtained by the lower 85% ET-rain treatment.

Selections of corn hybrid resulted in significant grain yield differences which emphasize the importance of this factor in intensification studies. Although both hybrids (Pioneer 1151 and Pioneer 1197) yielded exceptionally well, Pioneer 1197 averaged 9% greater grain yield, primarily due to a greater number of kernels/ear.

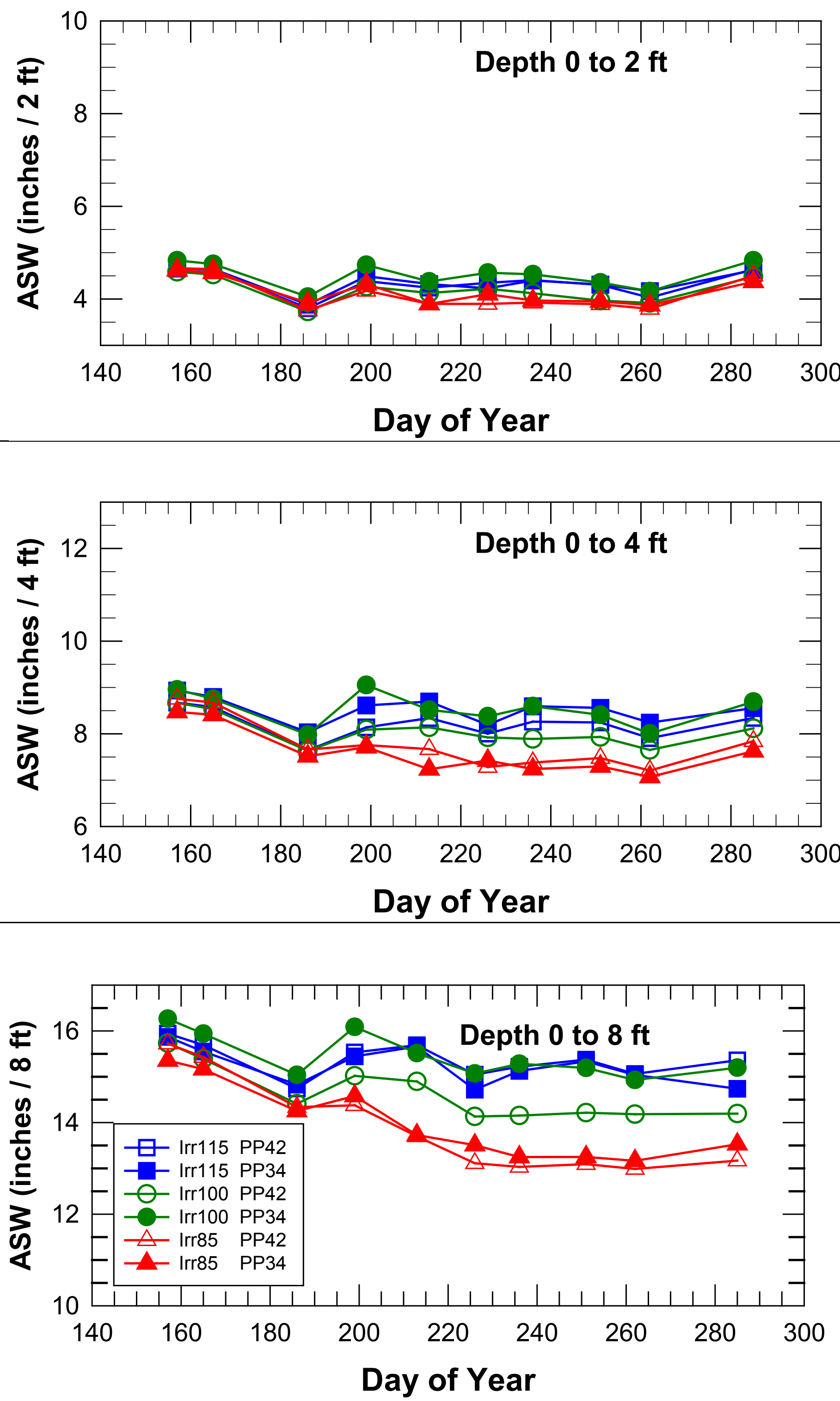

Figure 5. Available soil water for various soil profile depths for the three irrigation levels (115, 100, or 85% of ET –Rain) as affected by the highest and lowest corn plant densities (42,000 and 34,000 plants/acre).

Increasing plant density from 34,000 to 38,000 or 42,000 plants/acre also significantly increased grain yield. Although there were slight statistically nonsignificant reductions in kernel mass and statistically less kernels/ear for the greater plant densities , the 34,000 plant/acre plant density could not compensate enough in grain yield for its smaller number of plants. This reflects a growing understanding that to optimize high yielding corn production systems, the kernels per unit land area must be maximized (i.e., plant density x ears/plant x kernels/ear).

Intensification of corn production with SDI appears to be a promising approach to improving the use of our limited land and water resources. As we move forward with the research, it is likely that some other inputs will become a limiting factor in increasing crop yield. That is to be anticipated and can be addressed at that time. Essentially, all farming advances have led to intensification. As we move towards further intensification, we have to work wisely to do it in an environmentally, ecologically, and economically acceptable manner.

ACKNOWLEDGEMENTS

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