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# Effect of Subsurface Drip Irrigation Capacity and Nitrogen Fertigation Timing on Corn Production

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**Abstract.** A study was conducted at the KSU Northwest Research-Extension Center at Colby, Kansas in 2010 and 2012 to examine subsurface drip irrigation (SDI) capacity and nitrogen fertigation timing on corn production. Targeted SDI N fertigation events at 3 specific early season growth stages (V5, V9 or VT) were compared under 2 levels of irrigation (6.4 or 3.2 mm/day). Treatment effects were evaluated in terms of corn yield components, crop water use, and crop water productivity. Analysis indicates that conjunctive management of both irrigation and inseason N fertigation are important for corn production with SDI and that results are affected by annual weather conditions.

***Keywords.*** *Microirrigation, corn, nutrient management, irrigation, fertigation, nitrogen management*

## Introduction

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Research conducted at the KSU Northwest Research-Extension Center, Colby, Kansas has indicated that early season water stresses affecting subsurface drip irrigated corn can negatively affect the number of kernels per ear (Lamm and Aboukheira, 2011) and result in a grain yield reduction in drought years relative to alternative irrigation methods such as LEPA sprinklers (Lamm, 2004). However, kernel mass was generally improved by subsurface drip irrigation (SDI) in all years relative to LEPA (Lamm, 2004). This reduction in kernels/ear for SDI represents a management barrier to SDI adoption. Refined irrigation and management procedures can potentially remove this impediment.

Corn is sensitive to water stress at all stages of growth and grain yields are linearly related to water use from the dry matter threshold (the value of water use where grain yield begins to accumulate) up to the point of maximum yield. Deficit or limited irrigation of corn is difficult to implement successfully without reducing grain yields (Howell, et al., 1995; Lamm et al., 1993; Howell et al., 1989; Eck, 1986; Musick and Dusek, 1980; Stewart et al. 1975;). The corn vegetative stage is often considered the least-sensitive stage to water stress and could provide the opportunity to limit irrigation water applications without severe yield reductions. The vegetative stage begins at crop emergence and ends after tasseling, which immediately precedes the beginning of the reproductive period when the silks start to emerge. The potential number of ears/plant is established by the fifth leaf stage in corn. The potential number of kernels/ear is established during the period from about the ninth leaf stage until about one week before silking. Stresses during the 10 to 14 days after silking will reduce the potential kernels/ear to the final or actual number of kernels/ear. Therefore, in research studies designed to examine water stresses during the first one-half of the corn crop season, both ears/plant and kernels/ear might be critical factors. Plant water stress can cause kernel abortion if it occurs early enough in the post-anthesis period but is more often associated with poor grain filling and thus reduced kernel weight. An adequate level of nitrogen has been shown to be very important in the process of kernel initiation and set (Pearson and Jacobs, 1987; Below et al., 2000). This paper will report the results of a study where single fertigations of nitrogen were compared under two irrigation regimes to potentially enhance kernel numbers and ultimately corn yield.

## Methods and Materials

### Experimental Site Description

This experiment was conducted at the Kansas State University Northwest Research-Extension Center at Colby, Kansas, USA, during the period 2010 through 2012. A devastating hail storm occurred on August , 2011 that greatly reduced yields in that year. The research study was abandoned for that year, but the crop was harvested for grain. The deep Keith silt loam soil (Aridic Argiustolls) as described in more detail by Bidwell et al. (1980), can supply about 445 mm of available soil water from a 2.4-m soil profile. The climate can be described as semi-arid with a summer precipitation pattern and a long term average annual rainfall of approximately 480 mm. Average precipitation is approximately 300 mm during the May 15 through September 11 (120-day) growing period. The corn anthesis period typically occurs between July 15 and 20.

The treatments consisted of single N fertigation events in the amount of 78 kg N/a in the form of UAN 32-0-0 at 3 specific pre-anthesis growth stages, V5, V9 or VT (Ritchie et al.,1989) compared under 2 irrigation regimes limited to either 6.4 daily or every two days. An additional control treatment with irrigation limited to 6.4 mm/day did not receive any additional inseason fertigation. The seven treatments were replicated three times in a completely randomized block design. All plot areas received a pre-plant broadcast surface application of 140 kg N/ha in the form of UAN 32-0-0.

Irrigation and fertigation was provided to the study through an SDI system installed at the site in 2009. Low-flow Netafim brand dripline (model Typhoon 875) with a 0.3-m emitter spacing, nominal emitter discharge of 0.9 L/hr and 22-mm inside diameter was installed with a 1.5 m dripline spacing using a shank type injector at a depth of 0.35 m. The emitter exponent for this dripline was 0.45 and the manufacturer's coefficient of variation was approximately 2.5%. There were four driplines in each 6-m wide plot that were approximately 43 m long. Each plot was instrumented with a municipal-type flowmeter to record accumulated flow. Mainline pressure entering the driplines was first standardized to 138 kPa with a pressure regulator and then further reduced with a throttling valve to an approximate plot flowrate of 0.135 L/s, coinciding with an operating pressure of approximately 69 kPa. Irrigation water was supplied from an unlined surface reservoir to which groundwater was pumped for temporary storage.

### Crops and Cultural Practices

Corn (Pioneer brand hybrid 32N73) was planted at an approximate seeding rate of 78,500 plants/ha on May 3, 2010 and May 1, 2012, and emerged on May 22, 2010 and May 7, 2012, respectively.

Irrigation was scheduled using a weather-based water budget each year but was limited by the treatment to either 6.4 mm/day or 6.4 mm/2 days. Irrigations were scheduled whenever the calculated soil water depletion in the profile exceeded approximately 25 mm. The weather-based water budget was constructed using data collected from a NOAA weather station located approximately 600 m northeast of the study site. The reference evapotranspiration (ETr) was calculated using a modified Penman combination equation similar to the procedures outlined by Kincaid and Heermann (1974). The specifics of the ETr calculations used in this study are fully described by Lamm et al. (1987). A two year (2005 and 2006) comparison using weather data from Colby, Kansas of this estimation method to the ASCE standardized reference evapotranspiration equation which is based on FAO-56 (Allen et al.,1998) indicates that the modified-Penman values are approximately 1.5 to 2.8% lower. This is well within the accuracy of the resultant scheduling and irrigation application procedures. Basal crop coefficients (Kcb) were generated using FAO-56 (Allen et al.,1998) as a guide with periods adjusted to northwest Kansas growing period lengths. Crop evapotranspiration (ETc) was calculated as the product of Kcb and ETr. This method of calculating water use has been acceptable in past studies at Colby (Lamm and Rogers, 1983, 1985). In constructing the irrigation schedules, no attempt was made to modify ETc with respect to soil evaporation losses or soil water availability as outlined by Kincaid and Heermann (1974). Alfalfa-based ETr is considered to give better estimates than short-grass ETo in this region (Howell, 2007). Precipitation and irrigation were deposits into the crop water budget and calculated ETc was the withdrawal.

Pre-measured amounts of the inseason N fertigation were injected with diaphragm type positive displacement injection pumps into each appropriate plot separately over the course of a an approximately 15 minute period during a normal irrigation event. The injections were on June 23, 2010 and June 25, 2012 (V6 growth stage), July 6 2010 and 2012 (V9 growth stage), and July 23, 2010 and July 17, 2012 (VT growth stage), respectively.

### Experimental Data

Crop production data collected or calculated during the growing season included irrigation and precipitation amounts, weather data, yield components (grain and above-ground biomass yield, plant density, ears per plant, kernels/ear and kernel mass), and periodic soil water content.

Grain yield component data were measured by hand-harvesting a 6-m section of row near the center of the plot. The number of kernels/ear was not measured but was calculated by algebraic closure with the remaining grain yield components. Grain yield was standardized to 15.5% wet basis moisture content. Plant biomass at physiological maturity was determined by randomly selecting 5 contiguous corn plants from one of the center two rows of the plot. The plants were finely chopped in the field and dried in a forced-air forage oven at approximately 60°C for 3 days or longer. Plant material was periodically stirred by hand to allow for more uniform water evaporation.

Volumetric soil water content was measured weekly or biweekly with a neutron attenuation moisture meter in 0.3-m increments to a depth of 2.4 m at the crop row (approximately 0.38 m horizontally from the dripline). Water use values calculated after final data collection included seasonal water use and water productivity. Crop water use was calculated as the sum of soil water depletion between the initial and final soil water measurements, precipitation and irrigation between the initial and final soil water measurements. Calculating crop water use in this manner would inadvertently include any deep percolation and rainfall runoff. Water productivity was calculated as crop grain yield divided by total crop water use.

## Results and Discussion

### Weather Conditions and Irrigation Requirements

Weather conditions varied considerably between the two years (Figure 1). Weather for corn season 2010 averaged near normal with the calculated 120-day corn ETc being 584 mm, nearly equal to the long term (1972-2012) average of 585 mm and the precipitation during the same period being 281 mm just slightly less than the long term average of 300 mm. In contrast, 2012 calculated corn ETc was 694 mm with just 144 mm of seasonal precipitation. although the first 80 days were wetter than normal. The 2012 season resulted in the greatest recorded difference in calculated ETc and rainfall during the last 40 years of record. The fully irrigated treatment (limited to 6.4 mm/d) received 287 and 497 mm of irrigation in 2010 and 2012, respectively. The deficit irrigation treatment (limited to 6.4 mm/ 2 d) received 189 and 274 mm of irrigation in 2010 and 2012, respectively. Maximum daily temperatures were considerably greater in 2012 than 2010 with 25 days over 38°C in 2012 as compared to 5 days in 2010.

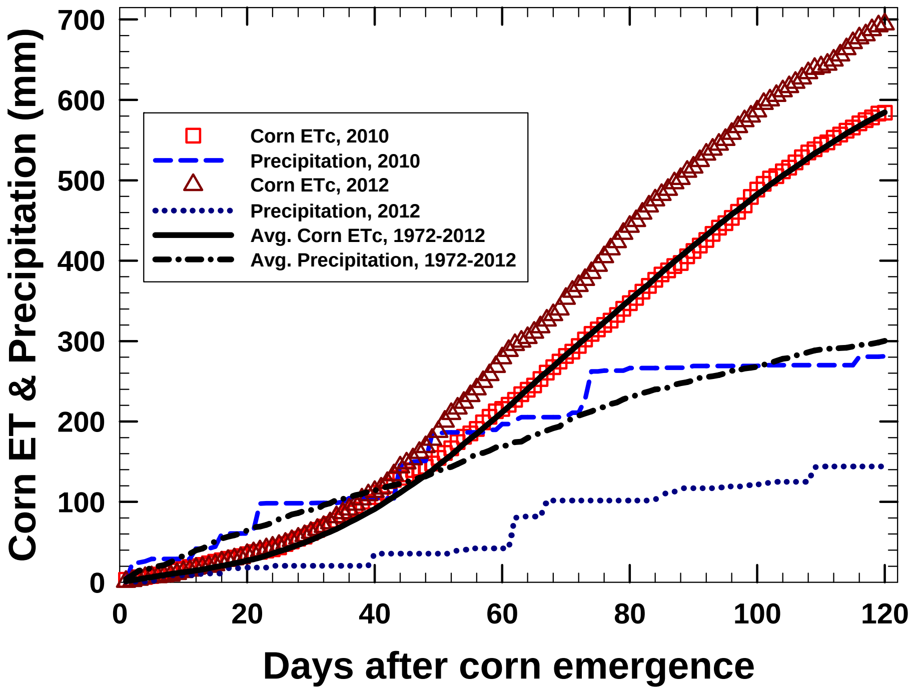

Figure 1. Cumulative calculated corn ETc and cumulative precipitation during the 120-day season for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas.

### Grain and Biomass Yields and Yield Components

Grain yields were excellent in both yields for all treatments receiving supplemental nitrogen fertigation ranging from 13.7 Mg/ha for the deficit irrigated V6 fertigation treatment in the drought year, 2012 to 17.4 for the fully irrigated V6 fertigation treatment in the normal weather year, 2010 (Table 1 and Figure 2). In general, irrigation level had a greater yield effect in the dought year 2012. Averaged over the two years, supplemental nitrogen fertigation at the V6 stage was most beneficial to grain yield response when the crop was fully irrigated, particularly in 2010. In contrast, timing of the nitrogen fertigation had little effect on the deficit irrigated treatments. When supplemental nitrogen fertigation was not added to the base 140 kg/ha preplant-applied nitrogen, corn grain yields were greatly reduced with a 44% reduction in the more normal year, 2010 and a 25% reduction in the drought year, 2012.

Differences in the intermediate yield component, kernels/area (i.e., plants/area x ears/plant x kernels/ear) could explain the corn grain yield differences for the fully irrigated V6 treatment in 2010 and for the non-fertigated treatment in both years (Table 1 and Figure 3). Generally, the potential kernel number is set between V6 and V9, while the actual kernel is finalized by about 2 weeks after pollination (R1 growth stage). The lack of the supplemental nitrogen fertigation had the greatest effect on kernels/area number in the more normal year 2010.

Kernel mass was greatest for the fully irrigated V6 fertigation treatment in 2010 and was much lower when there was no supplemental fertigation in both years (Table 1 and Figure 4). Timing of fertigation had little or no effect on kernel mass in the drought year 2012. The lack of the supplemental fertigation had the greatest effect on kernel mass in the more normal year 2010.

Appropriate timing of N fertigation had the greatest positive effect under full irrigation in the more normal year 2010, because of both greater kernels/area and much greater kernel mass.

**Table 1. Corn yield component, biomass and water use results from a subsurface drip irrigated corn study as affected by irrigation capacity and nitrogen fertigation timing, KSU Northwest Research-Extension Center, Colby Kansas, 2010 and 2012.**

| Irrigation capacity | N-Fertigation timing | Yield, Mg/ha | Kernels/area, Million Krnl/ha | Kernel mass, mg | Biomass, Mg/ha | Water use, mm | WP, Mg/ha-mm |
|---|---|---|---|---|---|---|---|
| ***Crop year, 2010*** | | | | | | | |
| 6.4 mm/d | None | 9.7 | 34.9 | 279 | 15.9 | 586 | 0.0166 |
| | V6 | 17.4 | 46.2 | 376 | 24.7 | 600 | 0.0290 |
| | V9 | 14.9 | 44.0 | 336 | 21.5 | 593 | 0.0251 |
| | VT | 15.0 | 43.5 | 345 | 21.7 | 601 | 0.0250 |
| Mean 6.4 mm/d | V6 thru V9 | 15.8 | 44.6 | 353 | 22.6 | 598 | 0.0264 |
| | | | | | | | |
| 6.4 mm/2 d | V6 | 15.2 | 47.0 | 323 | 18.5 | 558 | 0.0272 |
| | V9 | 14.9 | 46.2 | 324 | 21.1 | 552 | 0.0271 |
| | VT | 15.0 | 43.4 | 347 | 19.1 | 547 | 0.0275 |
| Mean 6.4 mm/2 d | V6 thru V9 | 15.0 | 45.5 | 331 | 19.6 | 552 | 0.0273 |
| **Crop year, 2012** | | | | | | | |
| 6.4 mm/d | None | 11.6 | 36.5 | 318 | 13.6 | 740 | 0.0157 |
| | V6 | 15.5 | 43.7 | 354 | 22.6 | 720 | 0.0215 |
| | V9 | 14.8 | 42.4 | 349 | 20.0 | 708 | 0.0209 |
| | VT | 15.6 | 44.3 | 352 | 23.0 | 663 | 0.0235 |
| Mean 6.4 mm/d | V6 thru V9 | 15.3 | 43.5 | 351 | 21.9 | 697 | 0.0220 |
| | | | | | | | |
| 6.4 mm/2 d | V6 | 13.7 | 38.9 | 353 | 20.7 | 490 | 0.0280 |
| | V9 | 13.9 | 39.7 | 349 | 19.8 | 566 | 0.0245 |
| | VT | 14.1 | 39.7 | 354 | 16.9 | 533 | 0.0264 |
| Mean 6.4 mm/2 d | V6 thru V9 | 13.9 | 39.4 | 352 | 19.1 | 530 | 0.0263 |
| **Mean, all years** | | | | | | | |
| 6.4 mm/d | None | 10.7 | 35.7 | 299 | 14.8 | 663 | 0.0161 |
| | V6 | 16.4 | 45.0 | 365 | 23.6 | 660 | 0.0252 |
| | V9 | 14.8 | 43.2 | 343 | 20.7 | 650 | 0.0230 |
| | VT | 15.3 | 43.9 | 348 | 22.4 | 632 | 0.0242 |
| Mean 6.4 mm/d | V6 thru V9 | 15.5 | 44.0 | 352 | 22.2 | 647 | 0.0242 |
| | | | | | | | |
| 6.4 mm/2 d | V6 | 14.4 | 42.9 | 338 | 19.6 | 524 | 0.0276 |
| | V9 | 14.4 | 42.9 | 337 | 20.5 | 559 | 0.0258 |
| | VT | 14.6 | 41.5 | 351 | 18.0 | 540 | 0.0270 |
| Mean 6.4 mm/2 d | V6 thru V9 | 14.5 | 42.5 | 342 | 19.3 | 541 | 0.0268 |

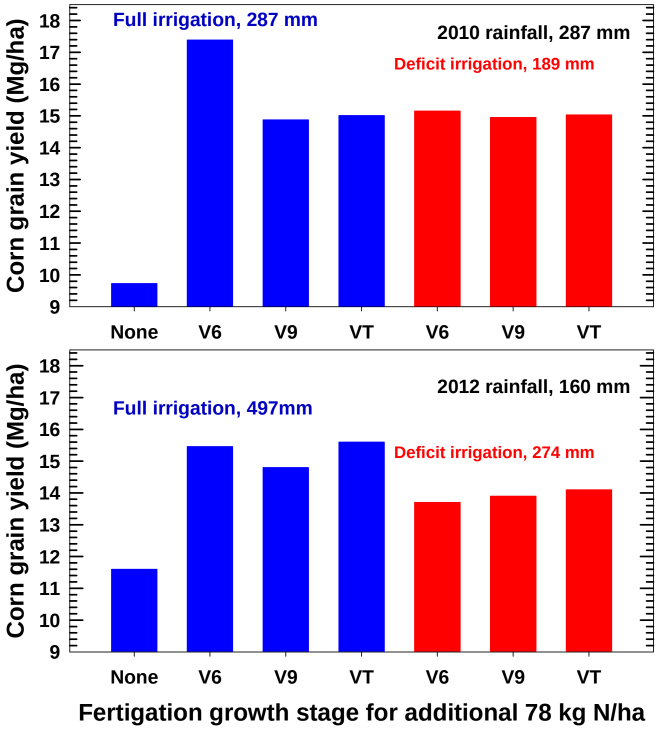

Figure 2. Corn grain yield as affected by irrigation regime and supplemental nitrogen fertigation timing for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2010 and 2012.

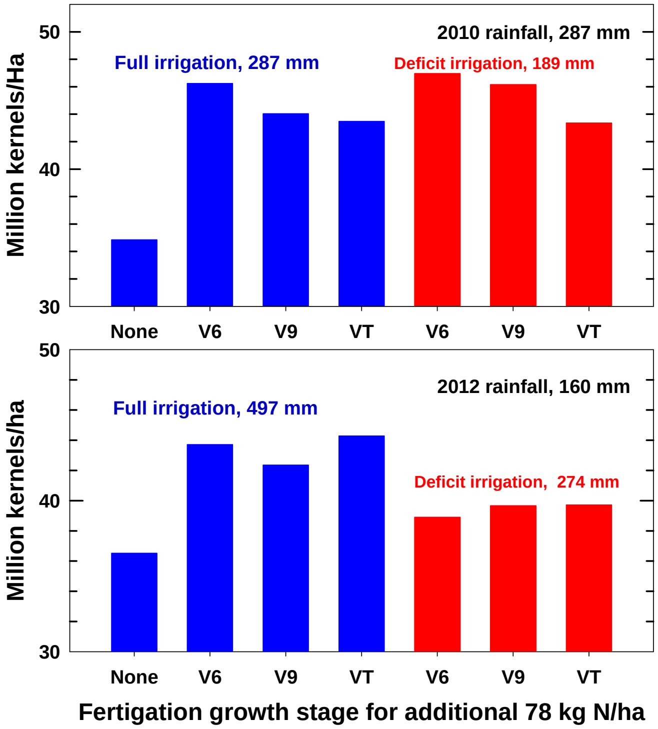

Figure 3. Kernels per unit land area as affected by irrigation regime and supplemental nitrogen fertigation timing for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2010 and 2012.

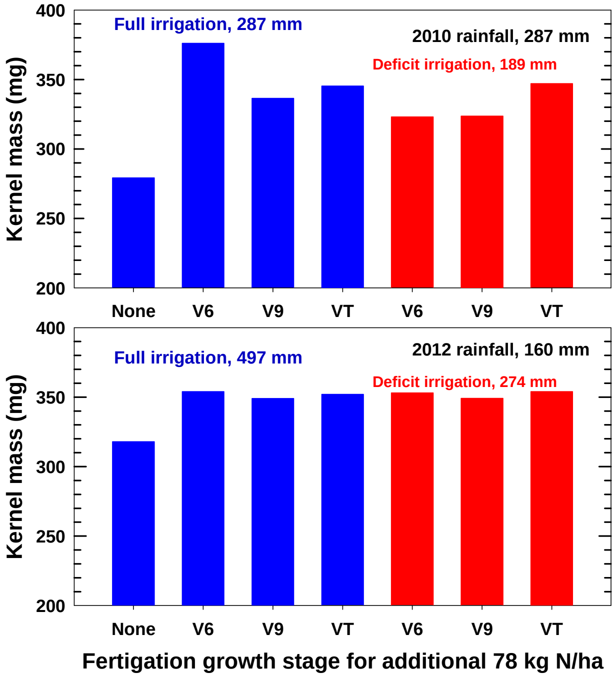

Figure 4. Kernel mass as affected by irrigation regime and supplemental nitrogen fertigation timing for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2010 and 2012.

Biomass was not consistently related to nitrogen fertigation timing between years (Figure 5), but when averaged across years there was a slight trend for greater biomass for earlier fertigation. Biomass was greatly reduced when no supplemental fertigation was applied. Biomass was generally greater for the fully irrigated fertigation treatments than for the deficit irrigated treatments.

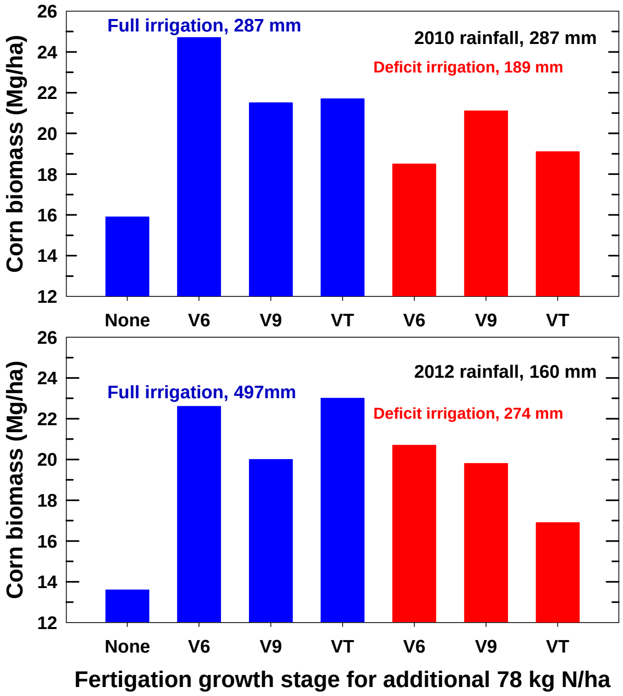

Figure 5. Corn above-ground biomass mass as affected by irrigation regime and supplemental nitrogen fertigation timing for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2010 and 2012.

## Water Use and Water Productivity

Seasonal corn water use was not affected by nitrogen fertigation or its timing in 2010, but was somewhat greater for the full irrigation treatments as might be anticipated (Figure 6). In 2012, corn water use was much greater for the fully irrigated treatments than in 2010, but was similar to 2010 values for the deficit irrigation treatments. Small numerical differences in water use were observed among the different fertigation timings in 2012, but these differences would not likely be statistically significant.

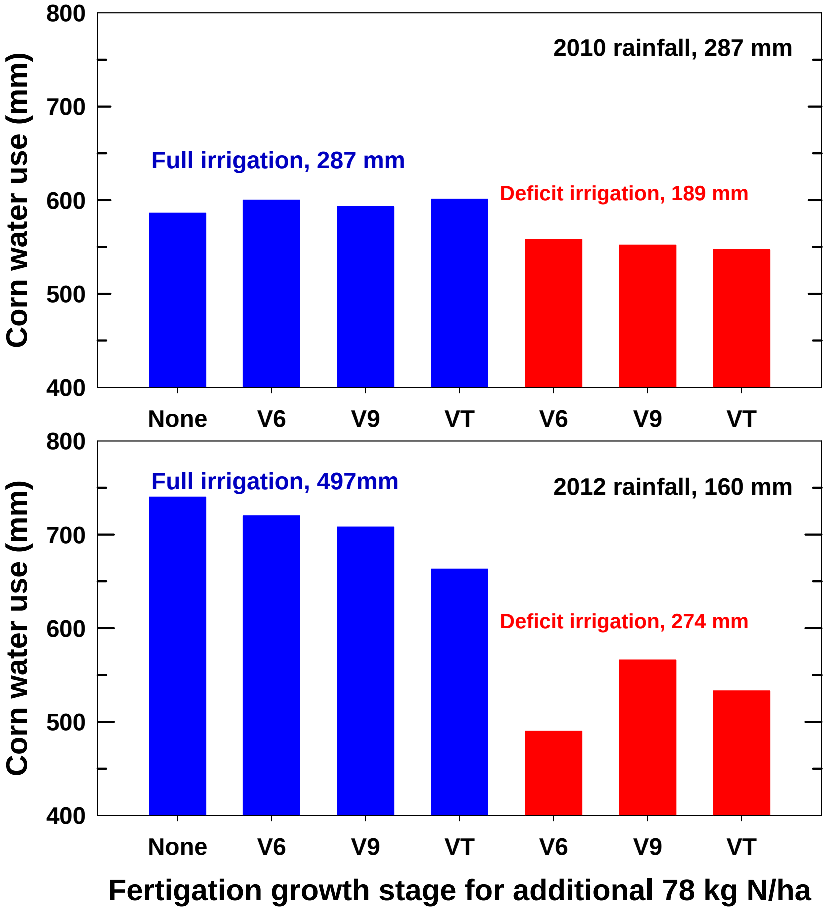

Figure 6. Corn water use as affected by irrigation regime and supplemental nitrogen fertigation timing for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2010 and 2012.

Corn water productivity was greater in 2010 than 2012, reflecting the better growing conditions and were somewhat similar across all fertigated treatments. Often deficit irrigation treatments will obtain greater water productivity values than fully irrigated treatments. Perhaps, the lack of large differences in 2010 is indicative of the improved water management that subsurface drip irrigation can provide. However in 2012, the deficit irrigated treatments did have greater water productivity than the fully irrigated treatments. Yields were reduced in 2012 from 2010 levels, probably due to the excessive heat, and this may have capped the fully irrigated yields at a lower level. In both years, the lack of supplemental nitrogen fertigation greatly reduced water productivity. Grain yields were greatly reduced and water use was very similar for the non-fertigated treatment. This emphasizes that conjunctive management of both irrigation and inseason N fertigation are useful in optimizing corn production.

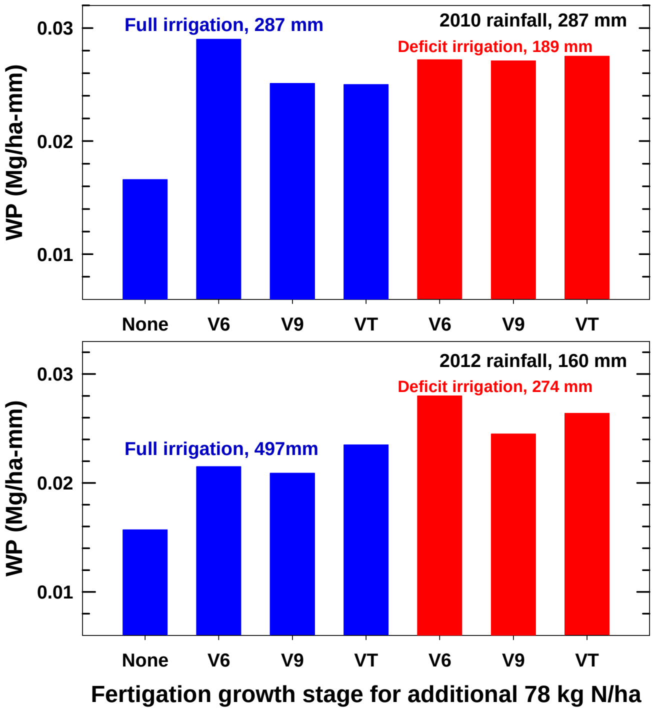

Figure 7. Corn water productivity (WP) as affected by irrigation regime and supplemental nitrogen fertigation timing for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2010 and 2012.

## Summary and Conclusions

Overall, corn grain yields, kernels/area, kernel mass, and water productivity generally were numerically greater when nitrogen fertigation timing was earlier in the crop growth and development. The greatest corn grain yield and greatest water productivity was obtained in 2010 by the fully irrigated treatment receiving supplement nitrogen fertigation at the V6 growth stage. The lack of supplemental nitrogen fertigation greatly reduced grain yields and water productivity in both years. Conjunctive management of both irrigation and inseason N fertigation are important for corn production with SDI.

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