2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Effect of Nitrogen Management on Severely Deficit Subsurface Drip-Irrigated Corn

Freddie R. Lamm[1]

Alan J. Schlegel[2]

[1] Kansas State University, Colby, Kansas, USA. flamm@ksu.edu

[2] Kansas State University, Tribune, Kansas, USA. schlegel@ksu.edu

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Abstract. *Deficit or limited irrigation is becoming a reality in many areas of the Great Plains. A study was conducted at the KSU Northwest Research-Extension Center at Colby, Kansas from 2004 to 2006 to examine the effect of nitrogen application method for severely deficit subsurface drip-irrigated corn. There were no significant differences in corn yields or water productivity between preplant-applied nitrogen and in-season fertigation for severely deficit-irrigated corn. Fertigation tended to establish more kernels per unit area in the drier years (2004 and 2006) when irrigation was limited to 75 mm and also in the wetter year (2005) when increased irrigation (150 mm) allowed for an appreciable increase in overall kernel numbers. Greater kernels/area tended to also increase corn grain yield.*

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

Introduction

Deficit or limited irrigation is becoming a reality in many areas of the Great Plains. 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.

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 conducted at the KSU Northwest Research-Extension Center at Colby, Kansas from 2004 to 2006 examining the effect of nitrogen application method and timing for severely deficit subsurface drip-irrigated corn.

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 2004 through 2006. 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 a 2 x 2 factorial randomized complete block design with two irrigation regimes and two nitrogen application methods. The four treatments were:

1. 25 mm of irrigation at V5 growth stage and an additional 50 mm at anthesis (R1) with preplant ground application of N.
2. 25 mm of irrigation at V5 growth stage and an additional 50 mm at anthesis (R1) with nitrogen fertigation instead of preplant ground application of N.
3. 50 mm of irrigation at V5 growth stage, an additional 50 mm at anthesis (R1) and an additional 50 mm 2 weeks after anthesis with preplant ground application of N.
4. 50 mm of irrigation at V5 growth stage, an additional 50 mm at anthesis (R1) and an additional 50 mm 2 weeks after anthesis with nitrogen fertigation instead of preplant ground application of N.

Each of the four whole-plot treatments were replicated three times. The 8 corn row plots were approximately 60 m long and 6 m wide.

Irrigation and fertigation was provided to the study through an SDI system installed at the site in 1990. Low-flow Chapin brand dripline (model Turbulent Twinwall IV) with a 0.3-m emitter spacing, nominal emitter discharge of 0.6 L/hr and 16-mm inside diameter was installed with a 1.5 m dripline spacing using a shank type injector at a depth of 0.42 m. 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 0.126 L/s, coinciding with an operating pressure of approximately 69 kPa.

Crops and Cultural Practices

Preplant broadcast-applied nitrogen was applied to Treatments 1 and 3 in the form of UAN 32-0-0 at the rate of 224 kg/ha of nitrogen on April 27, 2004, April 18, 2005, and April 26, 2006. This elevated amount of applied nitrogen for deficit irrigated corn in this region was chosen to evaluate whether nitrogen application method would have an effect when nitrogen was non-limiting. Nitrogen fertigation through the SDI system (Treatments 2 and 4) was applied in a single application at the V5 growth stage on June 10, 2004, June 21, 2005 and June 13, 2006 in the form of UAN 32-0-0 at the rate of 224 kg/ha of nitrogen. All treatments received starter fertilizer banded at planting at a rate of 50 kg/ha P_2O_5 and 33 kg/ha of N in the forms of ammonium superphosphate and UAN 32-0-0, respectively.

Corn (Pioneer brand hybrid 35P12) was planted at an approximate seeding rate of 53,100 seeds/ha on April 28, 2004, May 5, 2005 and April 27, 2006 and emerged on May 10, 2004, May 15, 2005 and May 18, 2006, respectively.

Total irrigation was limited to the imposed limits of 150 mm (Trt 1 and 2) or 300 mm (Trt 3 and 4) but individual treatments had differing event dates and amounts (Table 1). Weather-based water budgets were 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. 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 water budgets, 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.

Table 1. Irrigation dates and amounts in a nitrogen management study for severely deficit-irrigated corn grown using SDI at the KSU Northwest Research-Extension Center, Colby, Kansas, 2004-2006.

<table>
<tr><th>Irrigation treatment</th><th>Nitrogen management treatment</th><th colspan="2">Date and Activity</th><th colspan="2">Date and Activity</th><th colspan="2">Date and Activity</th></tr>
<tr><td>75 mm</td><td>Preplant broadcast</td><td rowspan="4">June 10, 2004
June 25, 2005
June 13, 2006</td><td>Irrigation, 25 mm</td><td rowspan="4">July 19, 2004
July 17, 2005
July 14, 2006</td><td>Irrigation, 50 mm</td><td rowspan="4">August 2, 2004
July 31, 2005
July 28, 2006</td><td>-</td></tr>
<tr><td>75 mm</td><td>Fertigation</td><td>Irrigation, 25 mm plus fertigation</td><td>Irrigation, 50 mm</td><td>-</td></tr>
<tr><td>150 mm</td><td>Preplant broadcast</td><td>Irrigation, 50 mm</td><td>Irrigation, 50 mm</td><td>Irrigation, 50 mm</td></tr>
<tr><td>150 mm</td><td>Fertigation</td><td>Irrigation, 50 mm plus fertigation</td><td>Irrigation, 50 mm</td><td>Irrigation, 50 mm</td></tr>
</table>

Pre-measured amounts of the inseason N fertigation were injected at the V5 growth stage with diaphragm type positive displacement injection pumps into each appropriate plot separately over the course of an approximately 15 minute period during the first irrigation event (Table 1).

Experimental Data

Crop production data collected or calculated during the growing season included irrigation and precipitation amounts, weather data, yield components (grain 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. The intermediate yield component kernels/area was calculated by multiplying the plant density, ears/plant and the kernels/ear together. 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

Weather conditions varied between years (Figure 1). Calculated well-watered 120-day corn ETc in all three years was near the long term (1972-2012) average of 585 mm. However growing season precipitation was 258, 306, and 226 mm for 2004, 2005 and 2006, respectively, as compared to the long term average of 300 mm. Precipitation in 2004 was near normal until mid August and then dry. Precipitation in 2005 was well above normal until early July and then a dry period began. In 2006, precipitation was below normal for the entire season. Maximum daily temperature exceeded 38°C for 3, 9 and 11 days in 2004, 2005, and 2006, respectively.

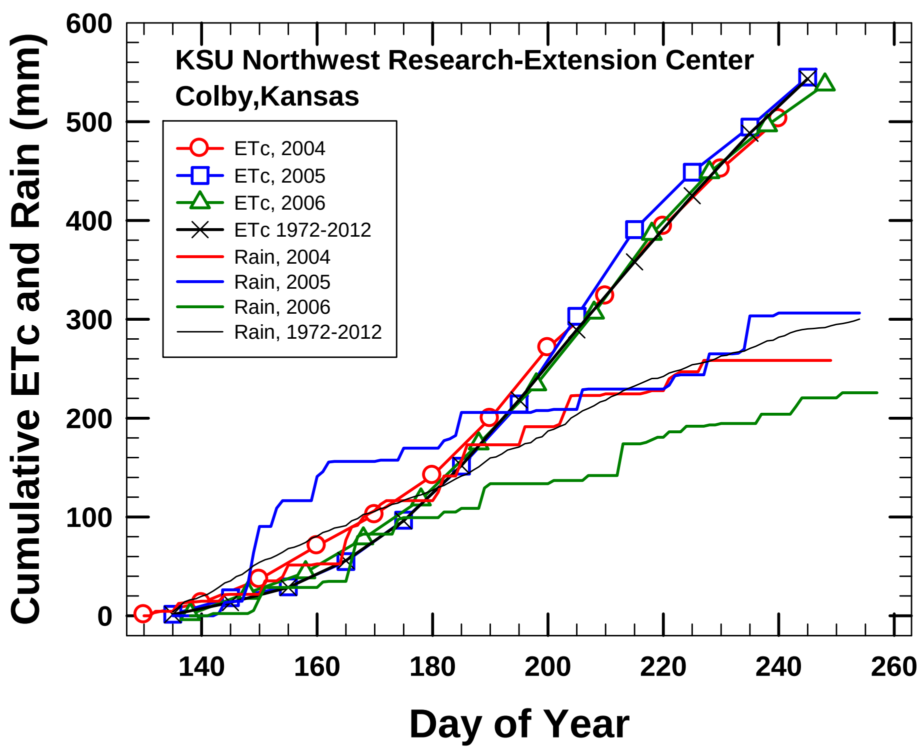

Figure 1. Cumulative well-watered calculated corn ETc and cumulative precipitation during the 120-day season for a subsurface drip irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas.

Grain and Biomass Yields and Yield Components

There were no statistically significant differences in corn yields between preplant-applied N and in-season fertigation for this severely deficit irrigated corn in any of the three years (Table 2 and Figure 2). When both precipitation and irrigation was more limited (i.e., Trts 1 and 2 receiving 75 mm of irrigation in 2004 and 2006) nitrogen fertigation tended to be more beneficial than broadcast preplant applied N. The potential benefit of nitrogen fertigation for SDI when precipitation and irrigation was limited may be because the N was at least partially positionally unavailable to the crop, thus lowering yields.

Fertigation tended to establish more kernels per unit area in the drier years (2004 and 2006) when irrigation was limited to 75 mm and also in the wetter year (2005) when increased irrigation (150 mm) allowed for an appreciable increase in overall kernel numbers (Figure 3 and Table 2.). The increased kernels/area in 2005 for the 150 mm irrigation regime may explain the greater numerical yield when the corn received fertigation (Figure 2). Conversely, at the 75 mm irrigation level, fertigation tended to lower kernel numbers in the drier years. Potentially, there was too much fertilizer available for the crop's prospects at the initiation of kernel set.

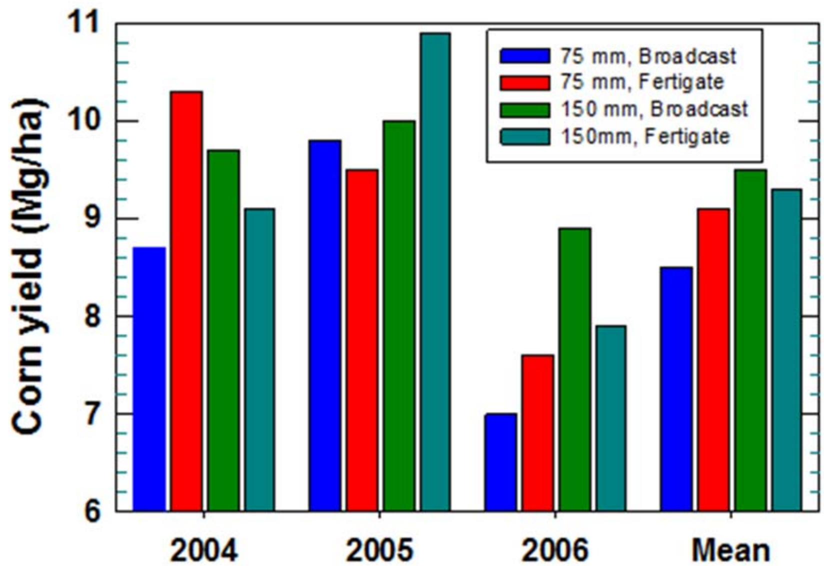

Figure 2. Corn grain yield as affected by irrigation regime and nitrogen application method for a severely deficit subsurface drip-irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2004 through 2006.

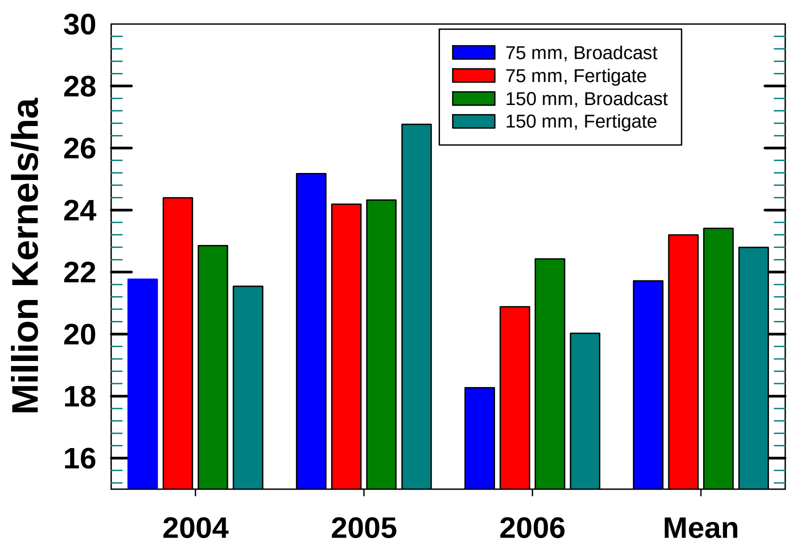

Figure 3. Corn kernels/area as affected by irrigation regime and nitrogen application method for a severely deficit subsurface drip-irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2004 through 2006.

Table 2. Corn yield and water use data from a severely deficit-irrigated study comparing pre-plant applied nitrogen and inseason fertigation, KSU Northwest Research-Extension Center Colby, Kansas, 2004-2006.

Irrigation and Nitrogen Treatment	Year	Irrigation (mm)	Yield (Mg/ha)	Kernels/area (million kernels/ha)	Kernel mass (mg)	Biomass (Mg/ha)	Total Water Use (mm)	WP* (Mg/ha-mm)
25 mm at first irrigation	2004	75	8.7	21.8	399	15.0	744	0.0117
50 mm at silking	2005	75	9.8	25.2	390	13.7	523	0.0188
225 kg N/ha broadcast plant	2006	75	7.0	18.3	382	12.9	445	0.0158
	Mean	75	8.5	21.7	390	13.9	571	0.0154
25 mm at first irrigation	2004	75	10.3	24.4	422	14.0	719	0.0144
50 mm at silking	2005	75	9.5	24.2	394	16.7	508	0.0187
225 kg N/ha through SDI	2006	75	7.6	20.9	365	11.6	450	0.0169
	Mean	75	9.1	23.2	394	14.1	559	0.0167
50 mm at first irrigation	2004	150	9.7	22.8	427	15.7	645	0.0150
50 mm (silking) + 50 mm 2 wks later	2005	150	10.0	24.3	411	15.6	544	0.0184
225 kg N/ha broadcast plant	2006	150	8.9	22.4	400	12.8	498	0.0179
	Mean	150	9.5	23.4	413	14.7	562	0.0171
50 mm at first irrigation	2004	150	9.1	21.5	425	16.1	726	0.0125
50 mm (silking) + 50 mm 2 wks later	2005	150	10.9	26.8	406	18.9	549	0.0198
225 kg N/a through SDI	2006	150	7.9	20.0	395	13.5	505	0.0156
	Mean	150	9.3	22.8	409	16.2	594	0.0160

As would be anticipated, greater irrigation increased kernel mass within a given year. There were no consistent differences in kernel mass attributable to N application method (Figure 4 and Table 2). A comparison of the grain yield with kernels/area and kernel mass (Figures 2 through 4) suggests that grain yield followed the trend in kernels/area to a greater extent than with kernel mass.

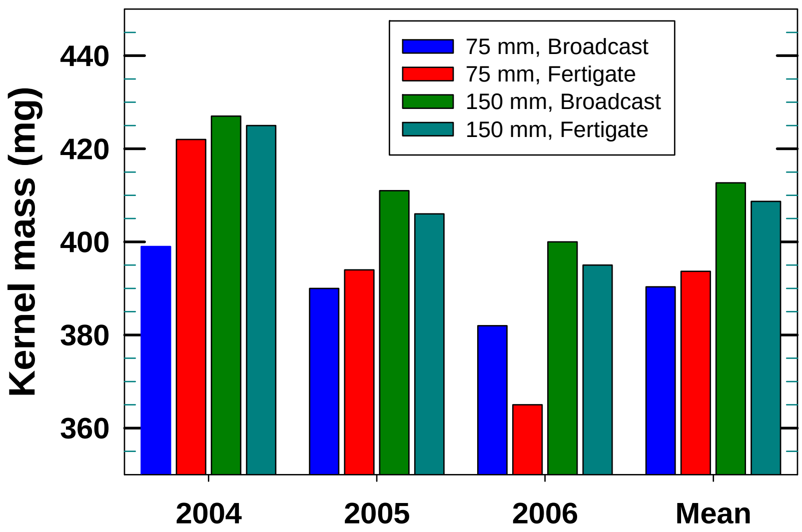

Figure 4. Corn kernel mass as affected by irrigation regime and nitrogen application method for a severely deficit subsurface drip-irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2004 through 2006.

Biomass tended to be greater when fertigation was practiced at the greater irrigation regime (150 mm) and for both irrigation regimes in the wetter crop year, 2005 (Figure 5 and Table 2). Nitrogen uptake by the crop was higher (data not shown) for the treatments receiving fertigation in 2005 and for the average of three years also resulting in greater biomass, but not statistically greater grain yields.

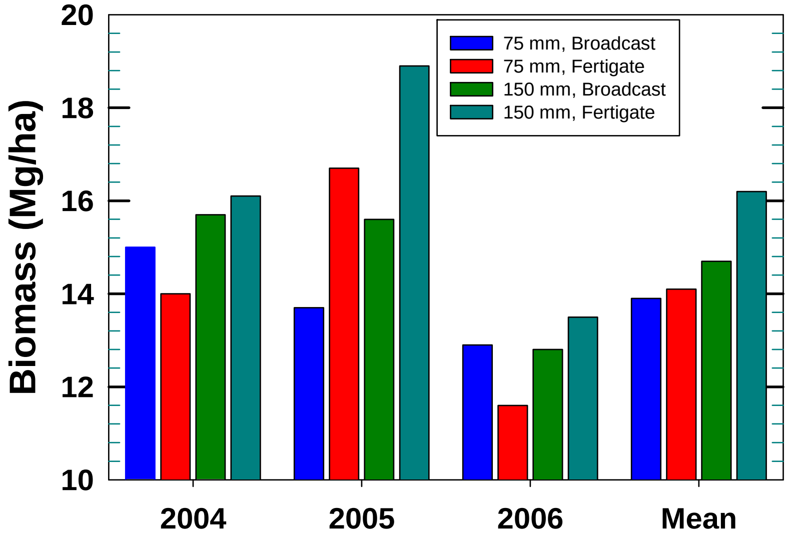

Figure 5. Above-ground corn biomass as affected by irrigation regime and nitrogen application method for a severely deficit subsurface drip-irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2004 through 2006.

Water Use and Water Productivity

There were significant differences in water use between treatments receiving 76 and 152 mm of irrigation in 2004 and 2006, but not in the wetter year, 2005 (Table 2). There were no appreciable differences in water productivity among the irrigation and nitrogen treatments, but results tended to follow the same trends as in crop yields (Table 2 and Figure 6). It can be noted these values are not particularly high, even though the amount of irrigation was low.

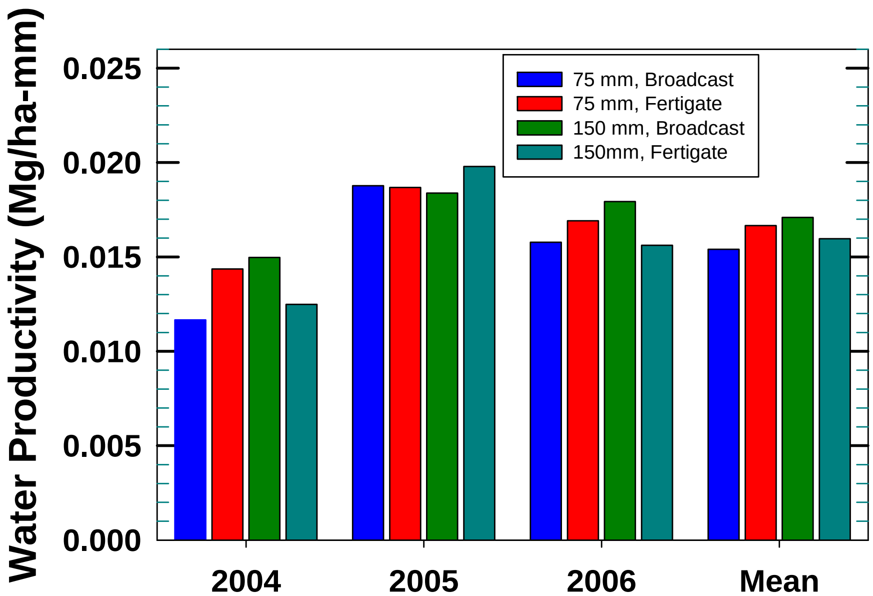

Figure 6. Water productivity as affected by irrigation regime and nitrogen application method for a severely deficit subsurface drip-irrigated corn study at the KSU Northwest Research-Extension Center, Colby, Kansas, 2004 through 2006.

Summary and Conclusions

Nitrogen fertigation can be beneficial to SDI in dry years by making the N positionally available to the crop. However, care should be exercised towards how much total N is being applied, not exceeding the crop's yield prospect. When precipitation and irrigation are anticipated to be greater, N fertigation can be beneficial to SDI by establishing an even greater kernel set. Since there were some situations where N-fertigation was detrimental, the irrigation and fertilization should be conjunctively managed with respect to water availability (precipitation, irrigation and soil water storage).

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