CONVENTIONAL, STRIP, AND NO TILLAGE CORN PRODUCTION UNDER DIFFERENT IRRIGATION CAPACITIES

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ABSTRACT

Corn production was compared from 2004 to 2006 for three plant populations (25,400, 28,600 or 32,000 plants /acre) under conventional, strip and no tillage systems for irrigation capacities limited to 1 inch every 4, 6 or 8 days. Corn yield increased approximately 12% from the lowest to highest irrigation capacity in these three years of varying precipitation and near normal crop evapotranspiration. Strip tillage and no tillage had 8.8% and 7% higher grain yields than conventional tillage, respectively. Results suggest that strip tillage obtains the residue benefits of no tillage in reducing evaporation losses without the yield penalty sometimes occurring with high residue. The small increases in total seasonal water use (< 1.5 inch) for strip tillage and no-tillage compared to conventional tillage can probably be explained by the higher grain yields for these tillage systems.

INTRODUCTION

Declining water supplies and reduced well capacities are forcing irrigators to look for ways to conserve and get the best utilization from their water. Residue management techniques such as no tillage or conservation tillage have been proven to be very effective tools for dryland water conservation in the Great Plains. However, adoption of these techniques is lagging for continuous irrigated corn. There are many reasons given for this lack of adoption, but some of the major reasons expressed are difficulty handling the increased level of residue from irrigated production, cooler and wetter seedbeds in the early spring which may lead to poor or slower development of the crop, and ultimately a corn grain yield penalty as compared to conventional tillage systems. Under very high production systems, even a reduction of a few percentage points in corn yield can have a significant economic impact. Strip tillage might be a good compromise between conventional tillage and no tillage, possibly achieving most of the benefits in water conservation and soil quality management of no tillage, while providing a method of handling the increased residue and increased early growth similar to conventional tillage. Strip tillage can retain surface residues and thus suppress soil evaporation and also provide subsurface tillage to help alleviate effects of restrictive soil layers on root growth and function. A study was initiated in 2004 to examine the effect of three tillage systems for corn production under three different irrigation capacities. Plant population was an additional factor examined because corn grain yield increases in recent years have been closely related to increased plant populations.

GENERAL STUDY PROCEDURES

The study was conducted under a center pivot sprinkler at the KSU Northwest Research-Extension Center at Colby, Kansas during the years 2004 to 2006. Corn was also grown on the field site in 2003 to establish residue levels for the three tillage treatments. The deep Keith silt loam soil can supply about 17.5 inches of available soil water for an 8-foot soil profile. The climate can be described as semi-arid with a summer precipitation pattern with an annual rainfall of approximately 19 inches. Average precipitation is approximately 12 inches during the 120-day corn growing season.

A corn hybrid of approximately 110 day relative maturity (Dekalb DCK60-19 in 2004 and DCK60-18 in 2005 and 2006) was planted in circular rows on May 8, 2004, April 27, 2005 and April 20, 2006, respectively. Three seeding rates (26,000, 30,000 and 34,000 seeds/acre) were superimposed onto each tillage treatment in a complete randomized block design.

Irrigation was scheduled with a weather-based water budget, but was limited to the 3 treatment capacities of 1 inch every 4, 6, or 8 days. This translates into typical seasonal irrigation amounts of 16-20, 12-15, 8-10 inches, respectively. Each of the irrigation capacities (whole plot) were replicated three times in pie-shaped sectors (25 degree) of the center pivot sprinkler (Figure 1). Plot length varied from to 90 to 175 ft, depending on the radius of the subplot from the center pivot point. Irrigation application rates (i.e. inches/hour) at the outside edge of this research center pivot were similar to application rates near the end of full size systems. A small amount of preseason irrigation was conducted to bring the soil water profile (8 ft) to approximately 50% of field capacity in the fall and as necessary in the spring to bring the soil water profile to approximately 75% in the top 3 ft prior to planting. It should be recognized that preseason irrigation is not a recommended practice for fully irrigated corn production, but did allow the three irrigation capacities to start the season with somewhat similar amounts of water in the profile.

The three tillage treatments (Conventional tillage, Strip Tillage and No Tillage) were replicated in a Latin-Square type arrangement in 60 ft widths at three different radii (Centered at 240, 300 and 360 ft.) from the center pivot point (Figure 1). The various operations and their time period for the three tillage treatments are summarized in Table 1. Planting was in the same row location each year for the Conventional Tillage treatment to the extent that good farming practices allowed. The Strip Tillage and No-Tillage treatments were planted between corn rows from the previous year.

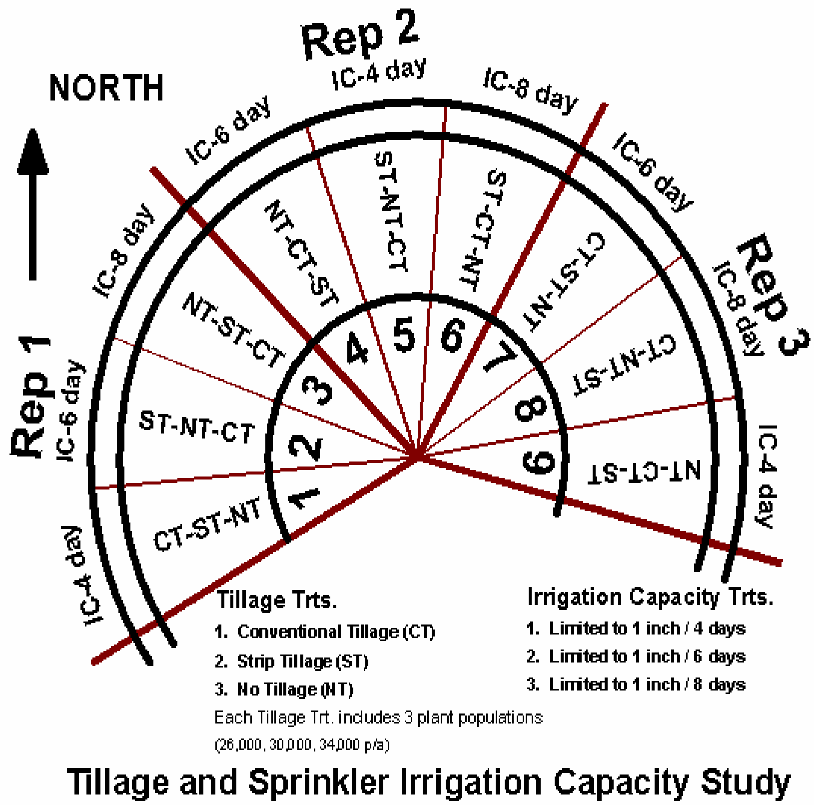

Figure 1. Physical arrangement of the irrigation capacity and tillage treatments.

Fertilizer N for all 3 treatments was applied at a rate of 200 lb/acre in split applications with approximately 85 lb/ac applied in the fall or spring application, approximately 30 lb/acre in the starter application at planting and approximately 85 lb/acre in a fertigation event near corn lay-by. Phosphorus was applied with the starter fertilizer at planting at the rate of 45 lb/acre P_2O_5. Urea-Ammonium-Nitrate (UAN 32-0-0) and Ammonium Superphosphate (10-34-0) were utilized as the fertilizer sources in the study. Fertilizer was incorporated in the fall concurrently with the Conventional Tillage operation and applied with a mole knife during the Strip Tillage treatment. Conversely, N application was broadcast with the No Tillage treatment prior to planting.

A post-plant, pre-emergent herbicide program of Bicep II Magnum and Roundup Ultra was applied. Roundup was also applied post-emergence prior to lay-by for all treatments, but was particularly beneficial for the strip and no tillage treatments. Insecticides were applied as required during the growing season.

Weekly to bi-weekly soil water measurements were made in 1-ft increments to 8-ft. depth with a neutron probe. All measured data was taken near the center of each plot. These data were utilized to examine treatment differences in soil water conditions both spatially (e.g. vertical differences) and temporally (e.g.

differences caused by timing of irrigation in relation to evaporative conditions as affected by residue and crop growth stage).

Table 1. Tillage treatments, herbicide and nutrient application by period.

Period	Conventional tillage	Strip Tillage	No Tillage
Fall 2003	1) One-pass chisel/disk plow at 8-10 inches with broadcast N, November 13, 2003.	1) Strip Till + Fertilizer (N) at 8-10 inch depth, November 13, 2003.	
Spring 2004	2) Plant + Banded starter N & P, May 8, 2004. 3) Pre-emergent herbicide application, May 9, 2004.	2) Plant + Banded starter N & P, May 8, 2004 3) Pre-emergent herbicide application, May 9, 2004.	1) Broadcast N + Plant + Banded starter N & P, May 8, 2004 2) Pre-emergent herbicide application, May 9, 2004.
Summer 2004	4) Roundup herbicide application near lay-by, June 9, 2004 5) Fertigate (N), June 10, 2004	4) Roundup herbicide application near lay-by, June 9, 2004 5) Fertigate (N), June10, 2004	3) Roundup herbicide application near lay-by, June 9, 2004 4) Fertigate (N), June 10, 2004
Fall 2004	1) One-pass chisel/disk plow at 8-10 inches with broadcast N, November 05, 2004.	*Too wet, no tillage operations*	
Spring 2005	2) Plant + Banded starter N & P, April 27, 2005. 3) Pre-emergent herbicide application, May 8, 2005.	1) Strip Till + Fertilizer (N) at 8-10 inch depth, March 15, 2005. 2) Plant + Banded starter N & P, April 27, 2005 3) Pre-emergent herbicide application, May 8, 2005.	1) Broadcast N + Plant + Banded starter N & P, April 27, 2005 2) Pre-emergent herbicide application, May 8, 2005.
Summer 2005	4) Roundup herbicide application near lay-by, June 9, 2005 5) Fertigate (N), June 17, 2005	4) Roundup herbicide application near lay-by, June 9, 2005 5) Fertigate (N), June 17, 2005	3) Roundup herbicide application near lay-by, June 9, 2005 4) Fertigate (N), June 17, 2005
Fall 2005	1) One-pass chisel/disk plow at 8-10 inches with broadcast N, November 10, 2005.	1) Strip Till + Fertilizer (N) at 8-10 inch depth, November 10, 2005.	
Spring 2006	2) Plant + Banded starter N & P, April 20, 2006. 3) Pre-emergent herbicide application, April 22, 2006.	2) Plant + Banded starter N & P, April 20, 2006 3) Pre-emergent herbicide application, April 22, 2006.	1) Broadcast N + Plant + Banded starter N & P, April 20, 2006 2) Pre-emergent herbicide application, April 22, 2006.
Summer 2006	4) Roundup herbicide application near lay-by, June 6, 2006 5) Fertigate (N), June 13, 2006	4) Roundup herbicide application near lay-by, June 6, 2006 5) Fertigate (N), June 13, 2006	3) Roundup herbicide application near lay-by, June6, 2006 4) Fertigate (N), June 13, 2006

Similarly, corn yield was measured in each of the 81 subplots at the end of the season. In addition, yield components (above ground biomass, plants/acre ears/plant, kernels/ear and kernel weight) were determined to help explain the treatment differences. Water use and water use efficiency were calculated for each subplot using the soil water data, precipitation, applied irrigation and crop yield.

RESULTS AND DISCUSSION

Weather Conditions

Summer seasonal precipitation was approximately 2 inches below normal in 2004, near normal in 2005, and nearly 3 inches below normal in 2006 at 9.99, 11.95 inches, and 8.99 inches, respectively for the 120 day period from May 15 through September 11 (long term average, 11.86 inches). In 2004, the last month of the season was very dry but the remainder of the season had reasonably timely rainfall and about normal crop evapotranspiration (Figure 2). In 2005, precipitation was above normal until about the middle of July and then there was a period with very little precipitation until the middle of August. This dry period in 2005 also coincided with a week of higher temperatures and high crop evapotranspiration near the reproductive period of the corn (July 17-25). In 2006, precipitation lagged behind the long term average for the entire season. Fortunately, seasonal evapotranspiration was near normal as it also was for the other two years (long term average of 23.07 inches).

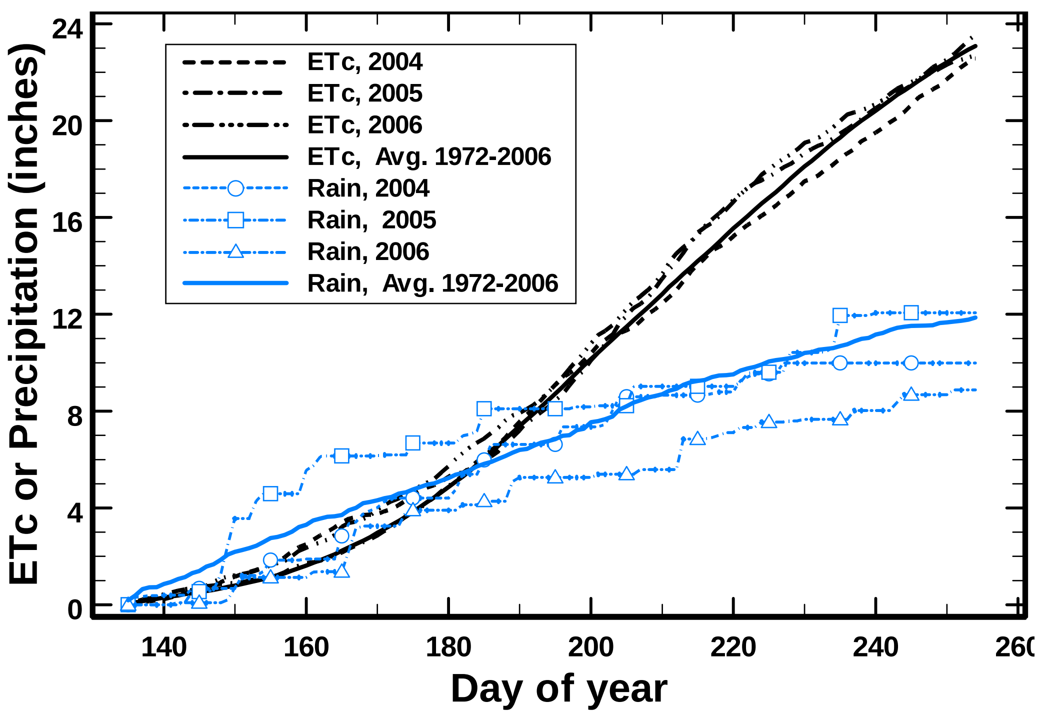

Figure 2. Corn evapotranspiration and summer seasonal rainfall for the 120 day period, May 15 through September 11, KSU Northwest Research-Extension Center, Colby Kansas.

Irrigation requirements were lowest in 2004 with the 1 inch/4 day treatment receiving 12 inches, the 1 inch/ 6 day treatment receiving 11 inches and the 1 inch/8 day treatment receiving 9 inches (Figure 3).

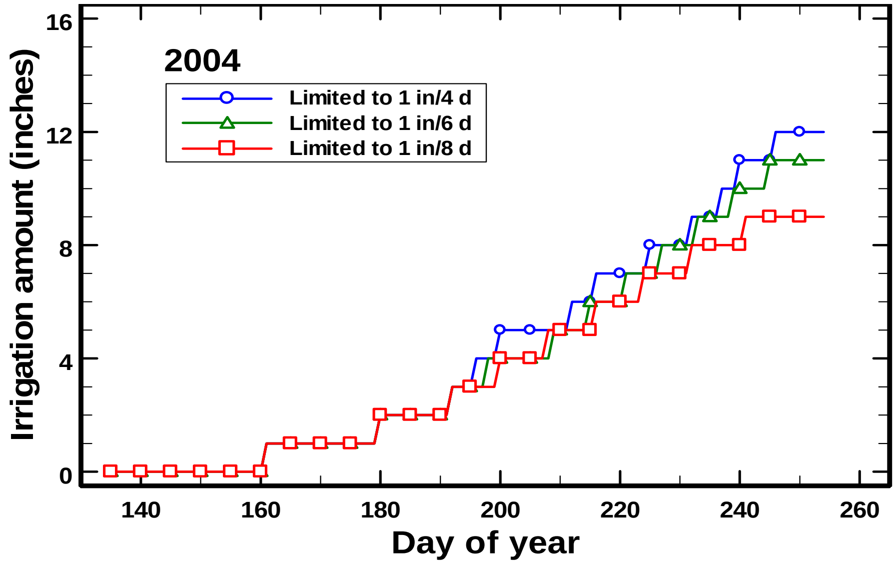

Figure 3. Seasonal irrigation for the 120 day period, May 15 through September 11, 2004 for the three irrigation treatments in an irrigation capacity and tillage study, KSU Northwest Research-Extension Center, Colby Kansas.

The irrigation amounts in 2005 were 15, 13, and 10 inches for the three respective treatments (Figure 4).

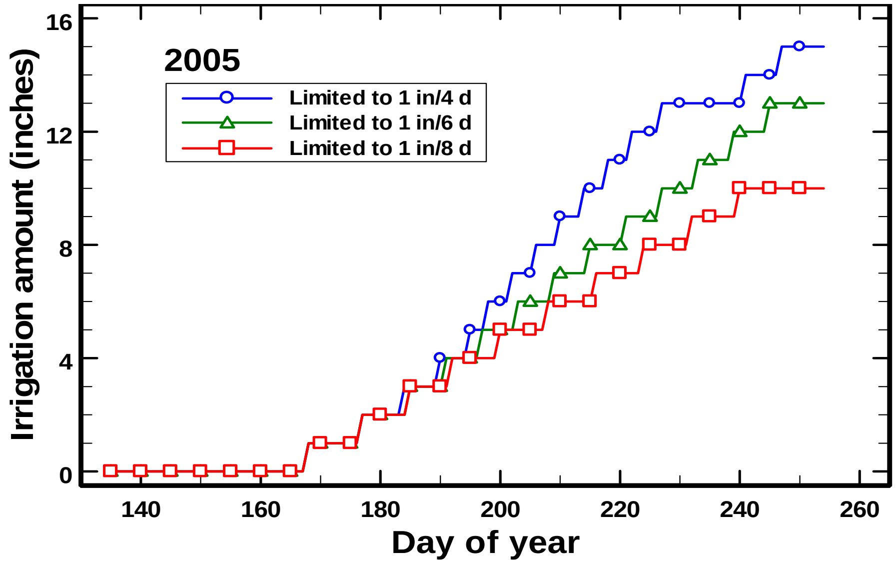

Figure 4. Seasonal irrigation for the 120 day period, May 15 through September 11, 2005 for the three irrigation treatments in an irrigation capacity and tillage study, KSU Northwest Research-Extension Center, Colby Kansas.

The irrigation amounts were highest in 2006 at 15.5, 13.5, and 11.50 inches for the three respective treatments (Figure 5).

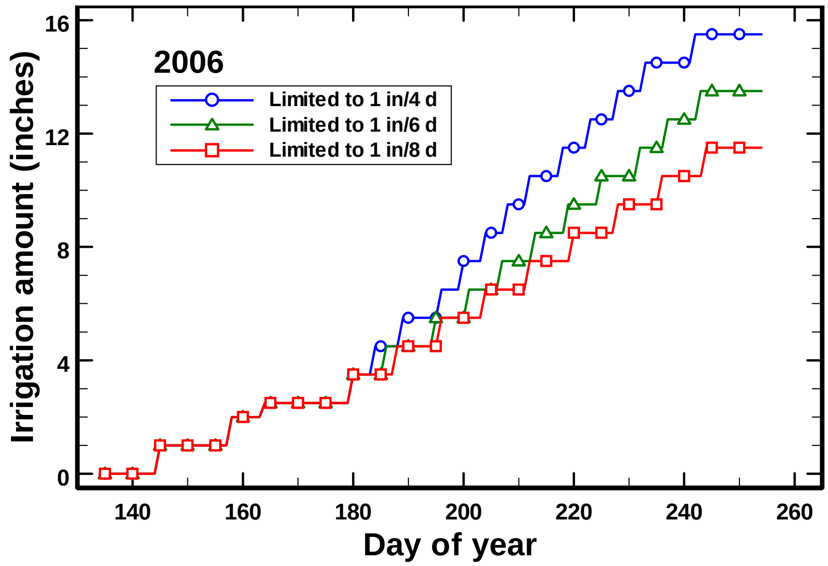

Figure 5. Seasonal irrigation for the 120 day period, May 15 through September 11, 2006 for the three irrigation treatments in an irrigation capacity and tillage study, KSU Northwest Research-Extension Center, Colby Kansas.

Crop Yield and Selected Yield Components

Corn yield was relatively high for all three years ranging from 161 to 262 bu/acre Table 2 through 4, and Figure 6). Higher irrigation capacity generally increased grain yield, particularly in 2005 and 2006. Strip tillage and no tillage had higher grain yields at the lowest irrigation capacity in 2004 and at all irrigation capacities in 2005 and 2006. Strip tillage tended to have the highest grain yields for all tillage systems and the effect of tillage treatment was greatest at the lowest irrigation capacity. These results suggest that strip tillage obtains the residue benefits of no tillage in reducing evaporation losses without the yield penalty sometimes associated with the higher residue levels in irrigated no tillage management.

Higher plant population had a significant effect in increasing corn grain yields (Tables 2 through 4, Figure 7) on the average about 10 to 20 bu/a for the lowest and highest irrigation capacities, respectively. Higher plant population gives greater profitability in good production years. Assuming a seed cost of $1.49/1,000 seeds and corn harvest price of $3.75/bushel, this 14 to 20 bu/acre yield advantage would increase net returns approximately $27 to $65/acre for the increase in plant population of approximately 6,100 seeds/acre. Increasing the plant population by 6100 plants/a on the average reduced kernels/ear by 48 and reduced kernel weight by 1.5 g/100 kernels (Tables 2 through 4). However, this was compensated by the increase in population increasing the overall number of kernels/acre by 12.8% (data not shown).

Table 2. Selected corn yield component and total seasonal water use data for 2004 from an irrigation capacity and tillage study, KSU Northwest Research-Extension Center, Colby, Kansas.

Irrigation Capacity	Tillage System	Target Plant Population (1000 p/a)	Grain Yield bu/acre	Plant Population (p/a)	Kernels /Ear	Kernel Weight g/100	Water Use (inches)
1 in/4 days	Conventional	26	229	27878	550	37.1	23.0
(12 inches)		30	235	29330	557	36.2	22.6
		34	234	32234	529	34.6	22.0
	Strip Tillage	26	245	27588	537	38.9	23.5
		30	232	30492	519	37.0	24.4
		34	237	33106	514	35.5	24.3
	No Tillage	26	218	25846	548	37.7	22.0
		30	226	29330	539	36.8	23.6
		34	251	33686	553	33.8	23.2
1 in/6 days	Conventional	26	226	25265	557	39.0	23.0
(11 inches)		30	222	29621	522	34.9	23.6
		34	243	32525	522	36.0	23.9
	Strip Tillage	26	235	27298	558	36.9	23.3
		30	224	28750	556	35.0	24.4
		34	237	33396	487	35.6	24.4
	No Tillage	26	225	26426	537	37.8	24.5
		30	222	29040	556	34.6	25.0
		34	229	32234	545	32.8	23.4
1 in/8 days	Conventional	26	198	24684	509	37.5	22.1
(9 inches)		30	211	29330	531	34.5	22.4
		34	216	31654	494	34.9	22.0
	Strip Tillage	26	227	25846	644	34.2	23.8
		30	229	29911	518	35.6	21.8
		34	234	32815	507	35.1	23.2
	No Tillage	26	220	27007	541	36.6	22.5
		30	225	29621	528	34.5	23.2
		34	220	32815	506	32.2	22.6

Table 3. Selected corn yield component and total seasonal water use data for 2005 from an irrigation capacity and tillage study, KSU Northwest Research-Extension Center, Colby, Kansas.

Irrigation Capacity	Tillage System	Target Plant Population (1000 p/a)	Grain Yield bu/acre	Plant Population (p/a)	Kernels /Ear	Kernel Weight g/100	Water Use (inches)
1 in/4 days	Conventional	26	218	23813	644	37.9	28.3
(15 inches)		30	238	27588	594	37.3	28.6
		34	260	30202	579	37.1	27.3
	Strip Tillage	26	238	24394	620	39.6	28.3
		30	251	27878	590	38.3	26.6
		34	253	31073	567	36.8	29.1
	No Tillage	26	228	24974	628	38.3	28.1
		30	254	26717	660	37.4	27.7
		34	262	31363	606	35.8	28.5
1 in/6 days	Conventional	26	203	24684	546	37.7	26.4
(13 inches)		30	221	27588	544	37.5	25.8
		34	208	31073	472	36.2	25.3
	Strip Tillage	26	226	24394	604	38.9	26.7
		30	207	28169	487	38.4	27.1
		34	248	31944	560	36.0	26.2
	No Tillage	26	205	24684	565	38.2	26.7
		30	224	29040	547	36.6	27.2
		34	234	31654	512	37.1	25.7
1 in/8 days	Conventional	26	187	24394	523	37.5	22.8
(10 inches)		30	218	27298	536	37.5	22.5
		34	208	31654	452	37.3	24.8
	Strip Tillage	26	212	23813	648	34.9	23.8
		30	216	27588	579	35.8	24.1
		34	240	31363	537	36.1	24.5
	No Tillage	26	208	24103	608	37.4	24.6
		30	211	27588	537	36.2	22.9
		34	216	31073	502	36.4	24.7

Table 4. Selected corn yield component and total seasonal water use data for 2006 from an irrigation capacity and tillage study, KSU Northwest Research-Extension Center, Colby, Kansas.

Irrigation Capacity	Tillage System	Target Plant Population (1000 p/a)	Grain Yield bu/acre	Plant Population (p/a)	Kernels /Ear	Kernel Weight g/100	Water Use (inches)
1 in/4 days	Conventional	26	239	29330	542	38.1	27.1
(15.5 inches)		30	213	31073	476	36.4	26.6
		34	212	35138	434	36.1	26.9
	Strip Tillage	26	232	29330	514	39.1	27.7
		30	236	31363	483	38.2	27.4
		34	260	33106	522	38.6	27.5
	No Tillage	26	211	28459	497	37.9	26.3
		30	263	31363	535	40.3	27.5
		34	248	34558	516	35.7	27.0
1 in/6 days	Conventional	26	161	29040	422	34.1	24.8
(13.5 inches)		30	208	31944	446	37.1	24.6
		34	169	33977	374	35.0	25.0
	Strip Tillage	26	207	29040	492	36.6	26.1
		30	215	31363	484	36.7	25.9
		34	216	34267	476	34.7	26.5
	No Tillage	26	230	29330	541	36.8	25.9
		30	218	30202	516	35.9	25.6
		34	223	32815	484	36.7	25.5
1 in/8 days	Conventional	26	172	28169	417	37.8	23.5
(11.5 inches)		30	191	31654	411	37.7	22.0
		34	191	33977	385	37.2	22.6
	Strip Tillage	26	214	29330	565	32.7	24.6
		30	220	31944	510	34.4	24.6
		34	230	34558	479	35.7	24.3
	No Tillage	26	204	28750	501	36.9	24.4
		30	220	31363	497	35.8	24.6
		34	216	33977	458	35.6	24.9

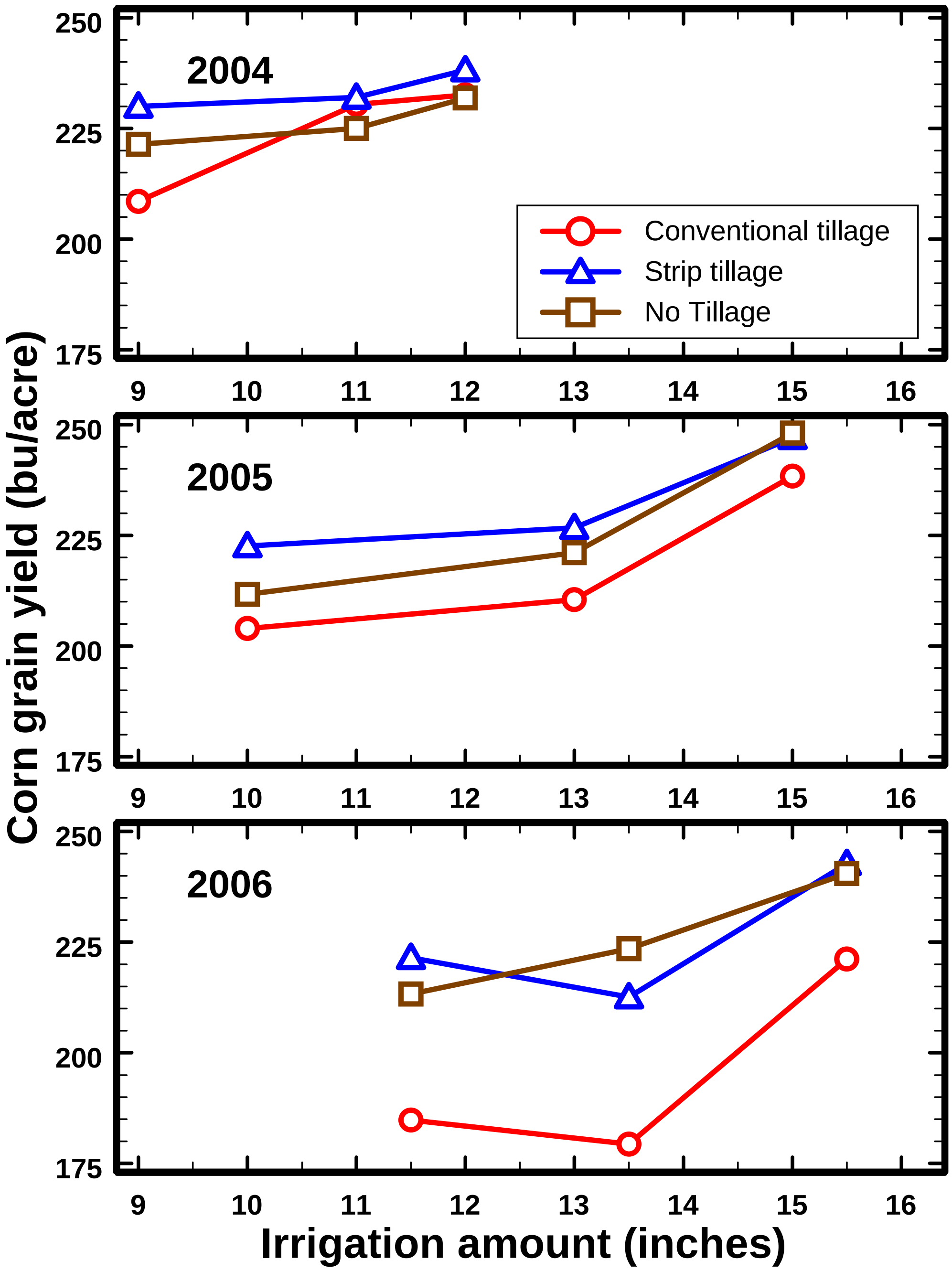

Figure 6. Corn grain yield as affected by irrigation capacity and tillage, 2004 to 2006, KSU Northwest Research-Extension Center, Colby Kansas.

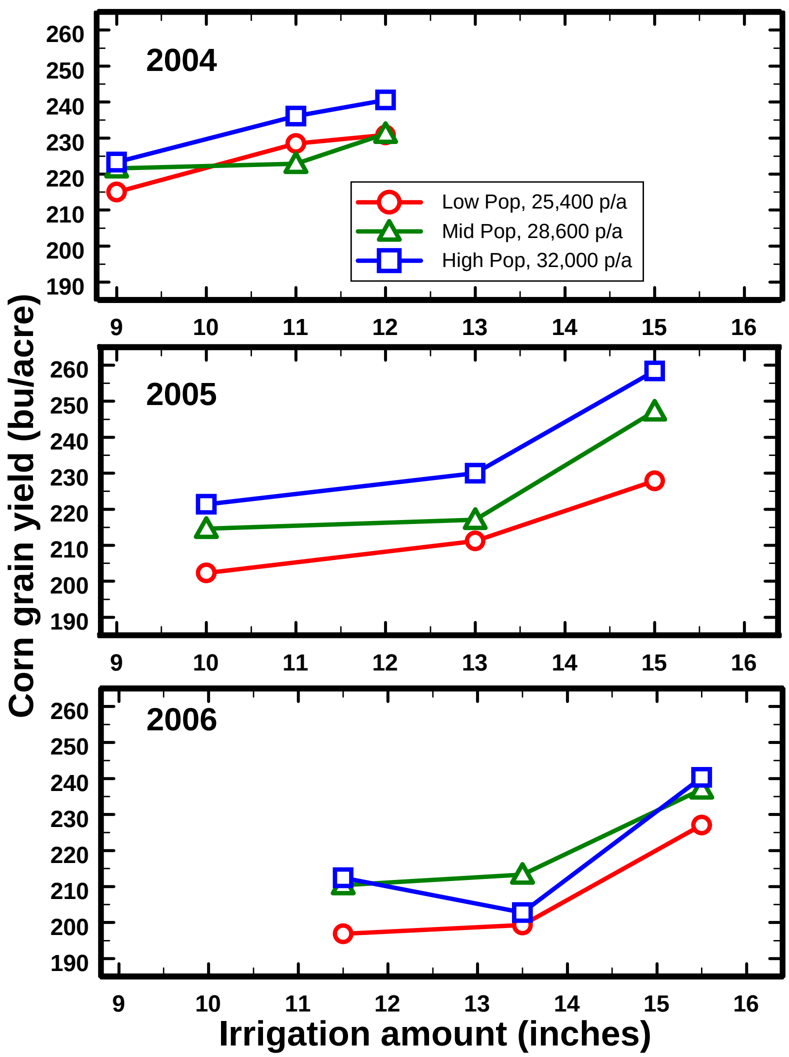

Figure 7. Corn grain yield as affected by irrigation capacity and plant population, 2004-2006, KSU Northwest Research-Extension Center, Colby Kansas.

The number of kernels/ear was lower in 2004 and 2006 compared to 2005 (Table 2 through 4, Figure 8). The potential number of kernels/ear is set at about the ninth leaf stage (approximately 2.5 to 3.5 ft tall) and the actual number of kernels/ear is finalized by approximately 2 weeks after pollination. Greater early season precipitation in 2005 (Figure 2) than 2004 and 2006 may have established a higher potential for kernels/acre and then later in the 2005 season greater irrigation capacity or better residue management may have allowed for more kernels to escape abortion. The time the actual kernels/acre was being set in 2005 was a period of high evapotranspiration (Figure 2) and also coincided with multiple irrigation events for the 1inch /4 days irrigation capacity.

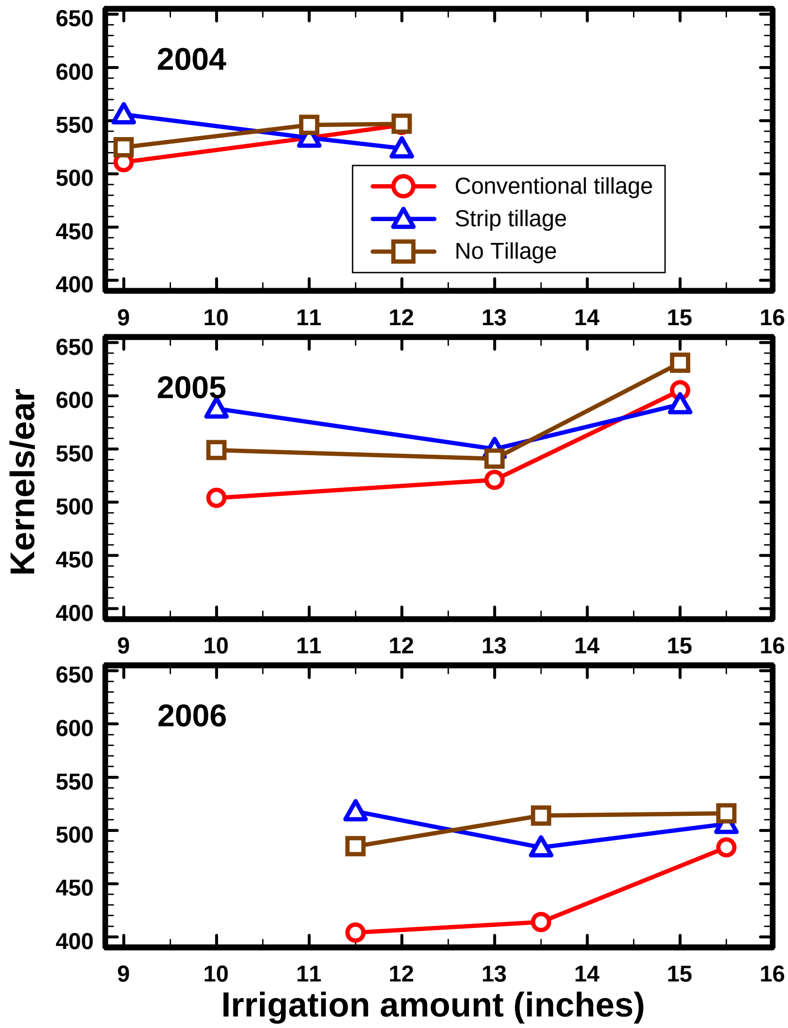

Figure 8. Kernels/ear as affected by irrigation capacity and plant population, 2004-2006, KSU Northwest Research-Extension Center, Colby Kansas.

Final kernel weight is affected by plant growing conditions during the grain filling stage (last 60 days prior to physiological maturity) and by plant population and kernels/ear. Deficit irrigation capacities often will begin to mine soil water reserves during the latter portion of the cropping season, so it is not surprising that kernel weight was increased with increased irrigation capacity (Tables 2 through 4, Figure 9). Tillage system also affected kernel weight, but it is thought by the authors that the effect was caused by different factors at the different irrigation capacities. At the lowest irrigation capacity, final kernel weight was highest for conventional tillage because of the lower number of kernels/ear. However, this higher kernel weight did not compensate for the decreased kernels/ear, and thus, grain yields were lower for conventional tillage. Strip tillage generally had higher kernel weights at higher irrigation capacity than the conventional and no tillage treatments for some unknown reason.

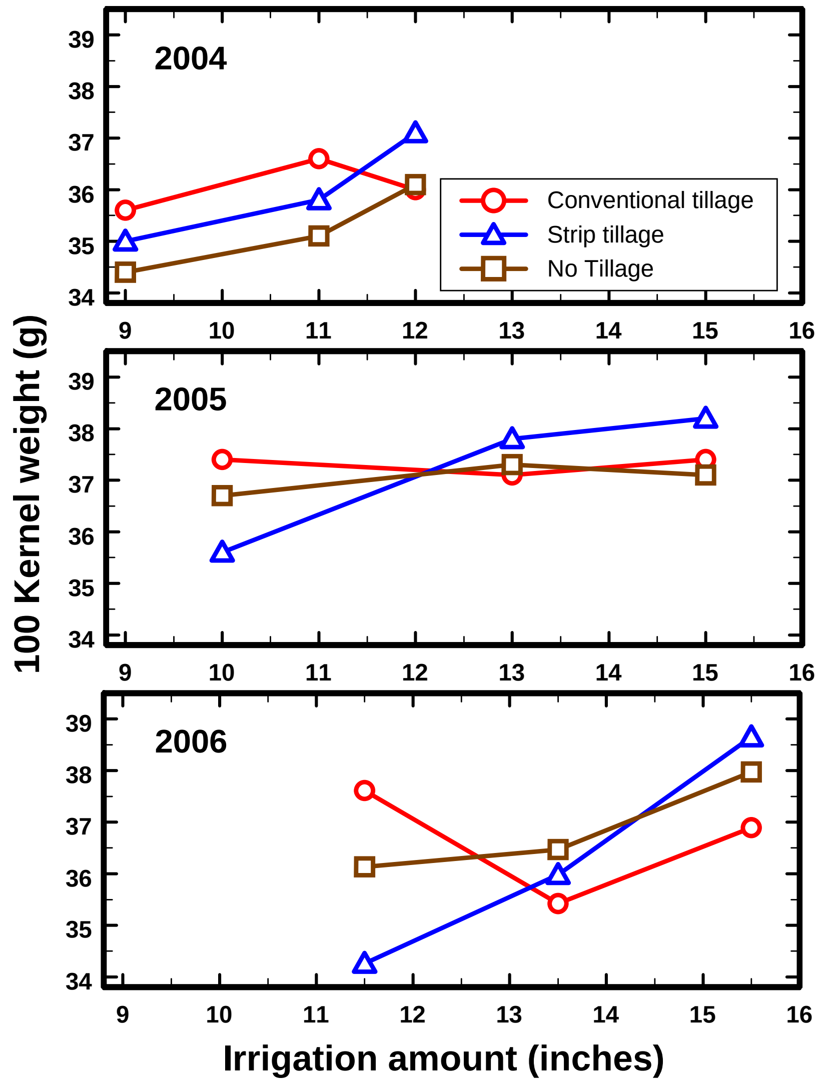

Figure 9. Kernel weight as affected by irrigation capacity and plant population, 2004-2006, KSU Northwest Research-Extension Center, Colby Kansas.

The changing patterns in grain yield, kernels/ear, and kernel weight that occurs between years and as affected by irrigation capacity and tillage system may be suggesting that additional factors besides differences in plant water status or evaporative losses is affecting the corn production. There might be differences in rooting, aerial or soil microclimate, nutrient status or uptake to name a few possible physical and biological reasons.

Total seasonal water use in this study was calculated as the sum of irrigation, precipitation and the change in available soil water over the course of the season. As a result, seasonal water use can include non-beneficial water losses such as soil evaporation, deep percolation, and runoff. Intuitively, one might anticipate that good residue management with strip tillage and no-tillage would result in lower water use than conventional tillage because of lower non-beneficial water losses. However, in this study, strip tillage and no-tillage generally had higher water use (Tables 2 through 4, Figure 10). The small increases in total seasonal water use (< 1.5 inch) for strip tillage and no-tillage compared to conventional tillage can probably be explained by the higher grain yields for these tillage systems (approximately 10 bu/a). Another possibility is that there were increased deep percolation losses in 2005 because of the higher early season precipitation.

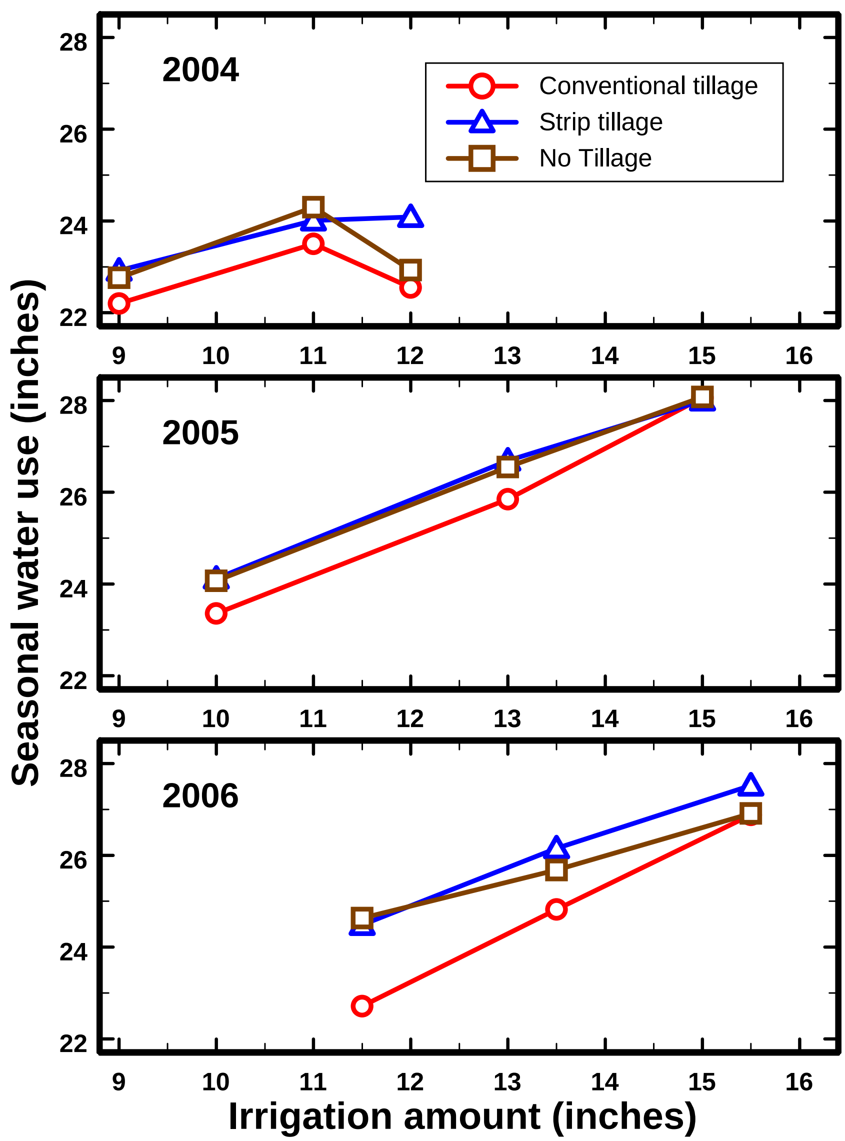

Figure 10. Total seasonal water use (sum of irrigation, precipitation, and seasonal changes in available soil water) as affected by irrigation capacity and plant population, 2004-2006, KSU Northwest Research-Extension Center, Colby Kansas.

CONCLUDING STATEMENTS

Corn grain yields were high all three years (2004 to 2006) with varying seasonal precipitation and near normal crop evapotranspiration. Strip tillage and no tillage generally performed better than conventional tillage. Increasing the plant population from 25,400 to 32,000 plants/acre was beneficial at all three irrigation capacities. The study will be continued in 2007 to determine if the production trends will remain as residue levels continue to increase.

ACKNOWLEGEMENTS

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Applying strip tillage treatments in the fall of 2005 in preparation for 2006 cropping season, KSU Northwest Research-Extension Center, Colby, Kansas.