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IRRIGATION RESEARCH WITH SUNFLOWERS IN KANSAS

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INTRODUCTION

Sunflower is a crop of interest in the Ogallala Aquifer region because of its shorter growing season and thus lower overall irrigation needs. Sunflowers are thought to better withstand short periods of crop water stress than corn and soybeans and the timing of critical sunflower water needs is also displaced from those of corn and soybeans. Thus, sunflowers might be a good choice for marginal sprinkler systems and for situations where the crop types are split within the center pivot sprinkler land area.

CURRENT IRRIGATED SUNFLOWER STUDY AT KSU-NWREC

Procedures

A study was conducted in 2009 and 2010 at the KSU Northwest Research-Extension Center in Colby, Kansas to examine the effect of three in-season irrigation capacities (limited to 1 inch every 4, 8, or 12 d) with and without a preseason irrigation application (5 inches applied in early May) on sunflower yield and water use parameters. All in-season irrigation events were scheduled using a weather-based water budget, so the irrigation capacities represent limits on irrigation not the actual applied amounts. Volumetric soil water content was measured in each subplot to a depth of 8 ft in one-foot increments on a weekly to biweekly basis throughout the crop production seasons.

Additionally, the irrigation treatments were superimposed with three target seeding rates of plant populations (18,000, 23,000 or 28,000 seeds/acre). A short stature hybrid (Triumph hybrid S671) was planted on June 18, 2009 and June 16, 2010 and the crop emerged on June 25, 2009 and June 24, 2010, respectively.

Sunflower yield and yield components (plant population, heads/plant, seeds/head and seed mass) seed oil quality, irrigation, total crop water use and crop water productivity (aka WUE and defined as Yield/Water Use) were determined for each subplot. The data was analyzed using statistical procedures from PC-SAS.

Results

Crop year 2009

The crop year 2009 was very cool and wet and irrigation needs were very low. In 2009, wet weather resulted in no irrigation being required before July 27, 2009. Irrigation amounts for the 1 inch every 4 and 8 days treatments were identical in 2009 at 2.88 inches (3 irrigation events) because the climatic water budget did not require the 1 inch every 4 days frequency to be used at maximum capacity. The 1 inch every 12 days had two irrigation events for a total of 1.92 inches over the course of the season. During the period April through October every month had above normal precipitation and between crop emergence and crop maturity the total precipitation was 10.18 inches.

There was a significant interaction of in-season irrigation capacity and plant population in 2009. The general trend was for greatest yields at the lowest and intermediate plant population (target plant populations of 18 and 23 K plants/acre) when in-season irrigation capacity was at intermediate or the greatest levels (1inch/8 days or 1 inch/4 days). At the lowest irrigation level, the trend was for the greatest yields at the intermediate and greatest plant population (Table 1). There were no other significant irrigation treatment effects on any yield component or water use parameter in 2009 (Table 1).

In 2009, plant population significantly affected all of the water use parameters and all of the sunflower yield components except seed yield and heads/plant (Table 1). The number of seeds/head and seed mass compensated for differences in plant population to achieve similar yield levels.

Crop year 2010

The early portion of the crop year 2010 was wet and irrigation needs were lower than normal. However, later in season, it was extremely dry with only 1.08 inches of precipitation occurring between August 4 and crop maturity on October 11. Wet weather resulted in no irrigation being required before July 25, 2010. In-season irrigation amounts were 11.52, 6.72, and 4.8 inches for the irrigation capacities limited to 1 inch/4 days, 1 inch/8 days and 1 inch/12 days, respectively. The 2010 sunflower irrigation amounts appear to be approximately 1 inch less than normal as estimated from long term (1972-2010) irrigation scheduling simulations conducted at Colby, Kansas.

There were no significant differences attributable to preseason irrigation on any yield component or water use parameter with the exception of plant population which was slightly decreased when preseason irrigation was performed (5 inches applied in late April) as shown in Table 2. The cause of this effect is unknown and perhaps should not be a concern at this time. So, preseason irrigation was an uneconomical practice in 2010 with the 5 inches of application costing approximately $17.50/acre (assuming a pumping cost of $3.50/acre-inch).

There were significant differences in yield and oil content with significantly lower yield and oil content occurring for the lowest irrigation capacity (limited to 1 inch/12 days for a total of 4.8 inches in 2010). Greatest yields and seed mass were obtained by the lowest target plant population (18,000 plants/acre) and at the greatest irrigation capacity (Table 2 and Figure 1). Oil content followed a different trend with greatest oil content occurring for the greatest target plant population (Table 2 and Figure 1). Oil yield for the 18,000 plants/acre population was 1357, 1361 and 1314 lbs/acre for the 1 inch/4 days, 1 inch/8 days and 1 inch/12 days irrigation capacities, respectively. Assuming a sunflower seed yield value of $0.213/lb and a pumping cost of 3.50/acre-inch, the 1 inch/8 days irrigation capacity would obtain $12.73 and $17.18 greater economic returns than the 1 inch/4 days and 1 inch/12 days irrigation capacities, respectively. Increases in plant population significantly decreased the seeds/head and seed mass as might be anticipated. Water use was increased by increased irrigation capacity as might be anticipated but was not affected by increases in plant population (Table 1). Water productivity (yield/water use) was significantly greater with decreases in irrigation capacity which is often the case, but must be balanced with the effect on overall economic productivity. The smallest plant population had significantly greater water productivity due to having a greater sunflower yield.

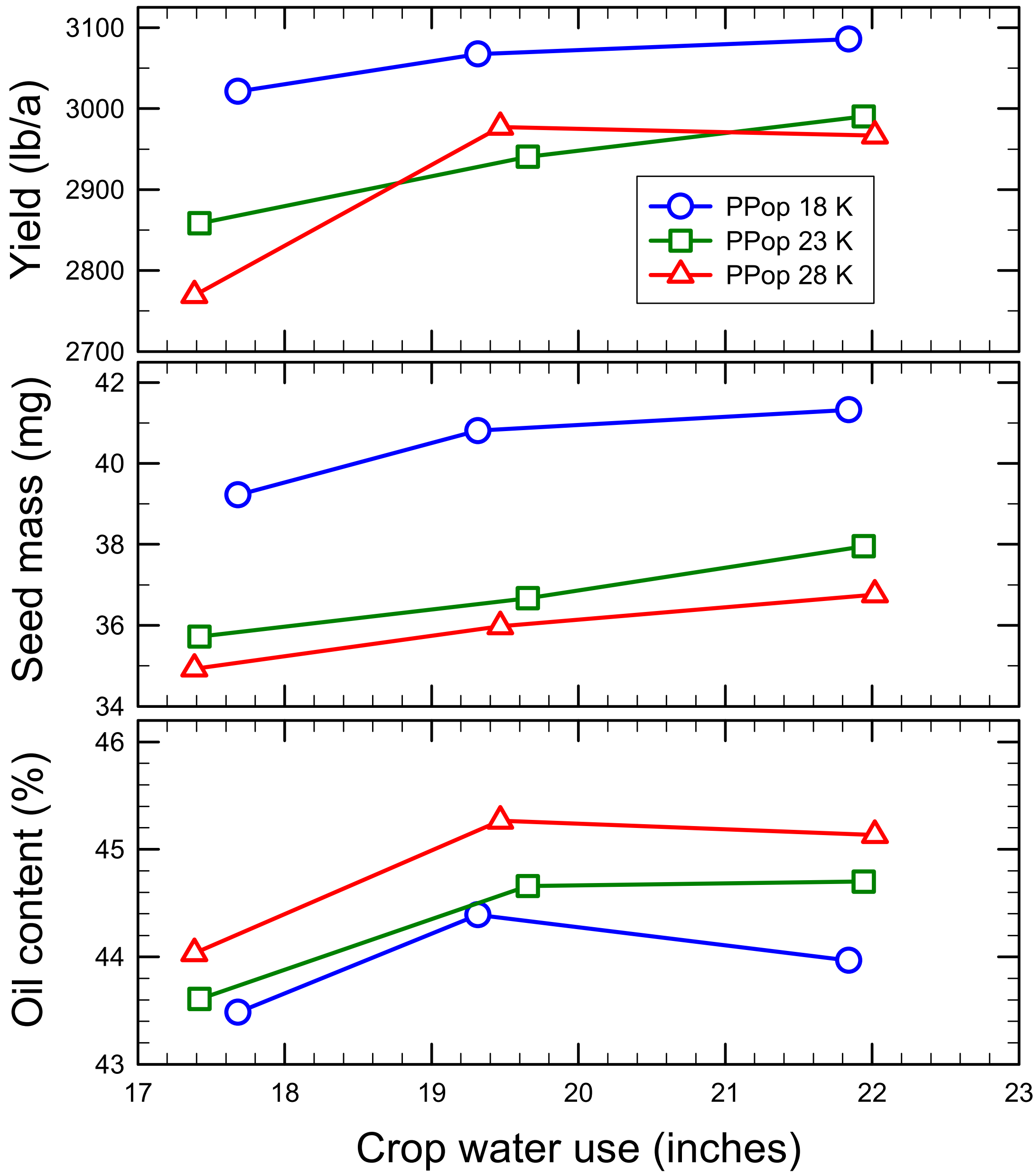

Figure 1. Sunflower yield, seed mass and oil content as related to total crop water use and the targeted plant population at KSU Northwest Research-Extension Center, Colby, Kansas in 2010. The three clusters of data points from left to right represent irrigation capacities of 1 inch/12 days (4.80 inches), 1 inch/8 days (6.72 inches) and 1 inch/4 days (11.52 inches), respectively.

Table 1. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2009, KSU Northwest Research-Extension Center, Colby Kansas.

Irrigation capacity	Preseason irrigation	Targeted plant pop (1000 p/a)	Yield (lb/a)	Harvest plant pop (p/a)	Heads /plant	Seeds /head	Seed mass (mg)	Seed Oil%	Water use (in)	Water productivity (lb/a-in)
1 in/4 d (2.88 in)	None	18	3266	16262	0.94	2114	46.6	45.6	17.14	191
		23	3324	20183	0.92	2043	40.2	46.2	17.69	189
		28	3109	23813	0.93	1720	37.2	46.6	17.30	180
		Mean	3233	20086	0.93	1959	41.3	46.2	17.38	186
	5 inches	18	3229	16553	0.94	2155	44.3	45.7	17.26	187
		23	3326	20328	0.93	1919	42.0	46.3	17.44	191
		28	3246	22942	0.99	1728	39.3	46.8	18.16	179
		Mean	3267	19941	0.95	1934	41.9	46.2	17.62	186
Mean 1 inch/4 days			**3250**	**20013**	**0.94**	**1947**	**41.6**	**46.2**	**17.50**	**186**
1 in/8 d (2.88 in)	None	18	3376	16698	0.95	2259	43.4	45.7	17.24	197
		23	3189	20183	0.95	1893	40.4	46.0	17.45	183
		28	3081	22506	0.96	1790	37.5	46.5	18.05	171
		Mean	3215	19796	0.95	1981	40.4	46.1	17.58	184
	5 inches	18	3427	16553	0.99	2214	42.8	45.0	17.72	193
		23	3208	19312	0.96	1934	40.6	46.1	17.37	185
		28	3332	22506	1.01	1766	38.4	46.6	18.17	184
		Mean	3322	19457	0.99	1971	40.6	45.9	17.76	188
Mean 1 inch/8 days			**3269**	**19626**	**0.97**	**1976**	**40.5**	**46.0**	**17.67**	**186**
1 in/12 d (1.92 in)	None	18	3158	16408	0.93	2198	42.8	45.7	17.50	181
		23	3186	19457	0.96	1923	40.3	45.9	17.87	178
		28	3168	24103	0.91	1728	38.3	46.5	17.87	178
		Mean	3171	19989	0.93	1950	40.5	46.0	17.75	179
	5 inches	18	3100	16117	0.97	2127	42.3	46.1	17.48	177
		23	3345	19166	0.96	1985	41.9	45.6	17.53	191
		28	3279	23522	0.94	1758	38.4	46.2	17.80	184
		Mean	3241	19602	0.96	1957	40.8	45.9	17.60	184
Mean 1 inch/12 days			**3206**	**19796**	**0.95**	**1953**	**40.7**	**46.0**	**17.68**	**182**
Study-Wide Mean			**3242**	**19812**	**0.95**	**1959**	**40.9**	**46.0**	**17.61**	**184**
Preseason Irrigation	None		**3206**	**19957**	**0.94**	**1963**	**40.7**	**46.1**	**17.57**	**183**
	5 inches		**3277**	**19667**	**0.97**	**1954**	**41.1**	**46.0**	**17.66**	**186**
Target plant population (1000 p/a)		18	**3260**	**16432 c**	**0.95**	**2178 a**	**43.7 a**	**45.6 c**	**17.39 b**	**188 a**
		23	**3263**	**19771 b**	**0.95**	**1950 b**	**40.9 b**	**46.0 b**	**17.56 b**	**186 a**
		28	**3203**	**23232 a**	**0.96**	**1748 c**	**38.2 c**	**46.5 a**	**17.89 a**	**179 b**

Values within the same shaded column are significantly different at P<0.05 when followed by a different lower-cased letter.

Table 2. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2010, KSU Northwest Research-Extension Center, Colby Kansas.

Irrigation capacity	Preseason irrigation	Targeted plant pop (1000 p/a)	Yield (lb/a)	Harvest plant pop (p/a)	Heads /plant	Seeds /head	Seed mass (mg)	Seed Oil%	Water use (in)	Water productivity (lb/a-in)
1 in/4 d (11.52 in)	None	18	3172	20038	0.94	1916	40.4	44.2	22.69	141
		23	2919	23668	0.89	1631	38.6	44.7	22.74	128
		28	2946	27007	0.85	1570	37.4	45.0	23.32	127
		Mean	3012	23571	0.90	1706	38.8	44.6	22.92	132
	5 inches	18	3000	19166	0.93	1845	42.3	43.8	20.99	143
		23	3062	23958	0.95	1646	37.3	44.7	21.15	146
		28	2987	25265	0.95	1597	36.1	45.3	20.72	145
		Mean	3172	20038	0.94	1916	40.4	44.2	22.69	141
Mean 1 inch/4 days			**3014 a**	**23184**	**0.92**	**1701**	**38.7**	**44.6 a**	**21.93 a**	**138 c**
1 in/8 d (6.72 in)	None	18	3043	19602	0.92	1893	41.0	44.5	19.63	157
		23	2989	23377	0.98	1668	36.1	44.6	20.01	150
		28	3004	25700	0.97	1563	35.7	45.3	19.36	156
		Mean	3012	22893	0.96	1708	37.6	44.8	19.66	154
	5 inches	18	3091	18440	0.98	1912	40.6	44.3	19.01	164
		23	2892	23087	0.93	1647	37.2	44.7	19.31	151
		28	2951	25410	0.98	1506	36.3	45.3	19.58	152
		Mean	3043	19602	0.92	1893	41.0	44.5	19.63	157
Mean 1 inch/8 days			**2995 a**	**22603**	**0.96**	**1698**	**37.8**	**44.8 a**	**19.48 b**	**155 b**
1 in/12 d (4.80 in)	None	18	2983	19312	0.96	1868	39.4	43.2	17.25	175
		23	2886	23522	0.96	1715	34.4	43.6	16.85	175
		28	2705	27588	0.88	1480	34.4	44.0	17.10	159
		Mean	2858	23474	0.93	1688	36.1	43.6	17.07	170
	5 inches	18	3059	19021	0.95	1983	39.0	43.7	18.12	170
		23	2831	22942	0.94	1613	37.0	43.6	17.99	158
		28	2833	26572	0.91	1511	35.5	44.1	17.67	162
		Mean	2908	22845	0.93	1702	37.2	43.8	17.93	163
Mean 1 inch/12 days			**2883 b**	**23159**	**0.93**	**1695**	**36.6**	**43.7 b**	**17.50 c**	**167 a**
Study-Wide Mean			**2964**	**22982**	**0.94**	**1698**	**37.7**	**44.4**	**19.64**	**153**
Preseason Irrigation	None		**2961**	**23313 a**	**0.93**	**1700**	**37.5**	**44.3**	**19.88**	**152**
	5 inches		**2967**	**22651 b**	**0.95**	**1695**	**37.9**	**44.4**	**19.39**	**155**
Target plant population (1000 p/a)		18	**3058 a**	**19263 c**	**0.94**	**1903 a**	**40.5 a**	**43.9 c**	**19.61**	**158 a**
		23	**2930 b**	**23426 b**	**0.94**	**1653 b**	**36.8 b**	**44.3 b**	**19.67**	**151 b**
		28	**2904 b**	**26257 a**	**0.92**	**1538 c**	**35.9 b**	**44.8 a**	**19.62**	**150 b**

Values within the same shaded column are significantly different at P<0.05 when followed by a different lower-cased letter.

Summary of Current Field Study

The crop year 2009 was too wet to gain much information on response of sunflower to irrigation, but there was the general trend of greater yields for lower or intermediate plant populations (target populations of 18,000 to 23,000 plants/acre and actual harvest populations of 16,500 to 19,800 plants/acre) under intermediate or higher irrigation capacities. In contrast, sunflower yield increased with greater plant population at the lowest irrigation level.

In 2010, a year that was wet in the early portion of the season, but very dry after August 4, sunflower seed yield increased with in-season irrigation capacity up until a capacity of 1 inch/8 days (6.72 inches total irrigation). The lowest plant population (target of 18,000 plants/acre and actual plant population of 19,300 plants/acre) gave the greatest yield (significant at $P<0.05$) and also had significantly greater seeds/head and seed mass.

Crop water use was slightly, but significantly greater ($P<0.05$) for the highest plant population in 2009 but was not affected in 2010. Crop water productivity was not affected by irrigation in 2009 but increased with decreased levels of irrigation in 2010. Increased plant population tended to decrease crop water productively primarily because of seed yield reduction.

The field study will be continued in 2011 because of the wetter than normal conditions experienced in 2009 and 2010.

RESULTS FROM EARLIER STUDIES AT KSU-NWREC

Irrigation studies with sunflower have been conducted periodically at the KSU Northwest Research-Extension Center since 1986. These irrigation treatments in these studies varied with some studies applying various percentages of well-water crop water use (ET), some studies applying water at specific sunflower growth stages, and some studies using water budget irrigation scheduling under various irrigation system capacities. Yield response varied some from year to year and some between studies as might be anticipated, but on the average 154 lbs of sunflower seed was obtained for each acre-inch of water use above a yield threshold of approximately 3 inches (Figure 2).

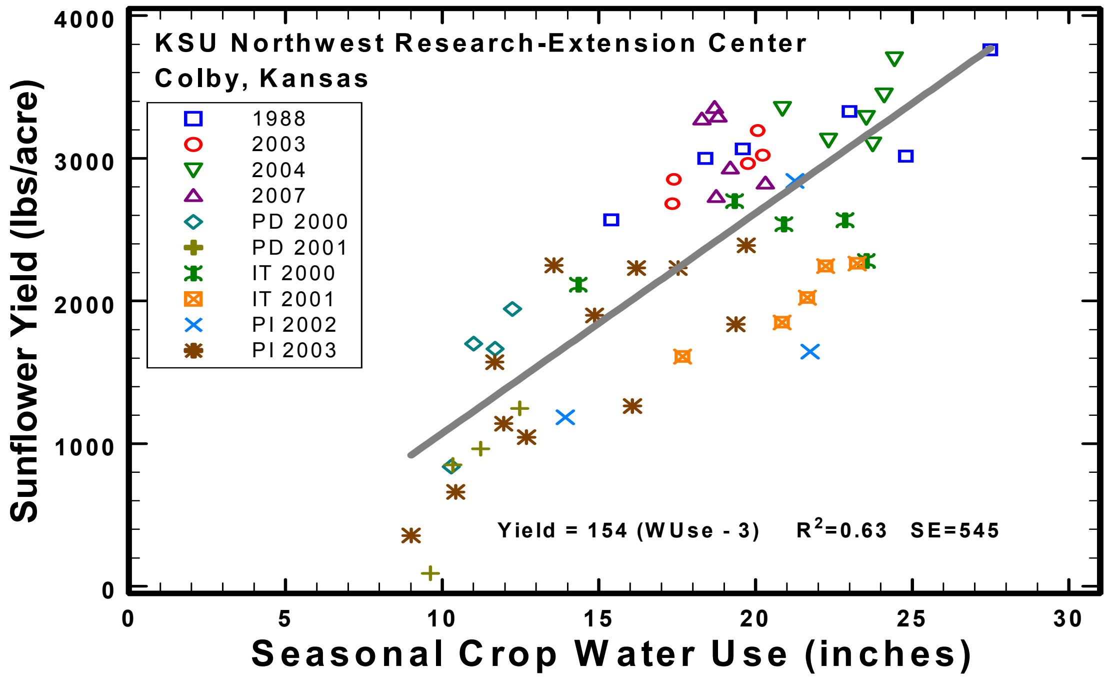

Figure 2. Sunflower yield response to total seasonal crop water use for selected studies conducted at the KSU Northwest Research-Extension Center, Colby Kansas, 1986-2007. The PD data from 2000 and 2001 was from dryland studies. The IT data from 2000 and 2001 was from studies scheduled by stage of growth. The data from the PI studies had irrigation applied at various growth periods throughout the summer. All other studies presented here were scheduled according to various percentages of crop water use.

RESULTS FROM SIMULATION MODELING

Thirty-nine years (1972-2010) of weather data was used to create simulated irrigation schedules for sunflower and also corn for a comparison crop. These irrigation schedules were also coupled with a crop yield model to estimate crop yield at various irrigation capacities (limited to 1 inch every 3, 4, 5, 6, 8, or 10 days) and under dryland production.

Although corn has greater crop water use (ET) and requires more irrigation (Figure 3) than sunflower, their peak water use rates and peak irrigation rates are very similar (Figure 4). Under full irrigation (a capacity not less than 1 inch every 4 days if needed), corn uses approximately 4.3 inches more water than sunflower during the season but only requires approximately 2.3 inches of additional irrigation because of its growth period encompasses some months of greater rainfall. Although peak ET and peak irrigation needs are similar between the two crops, sunflower's needs are for a much shorter duration and occur at a time when corn's needs are about to start declining.

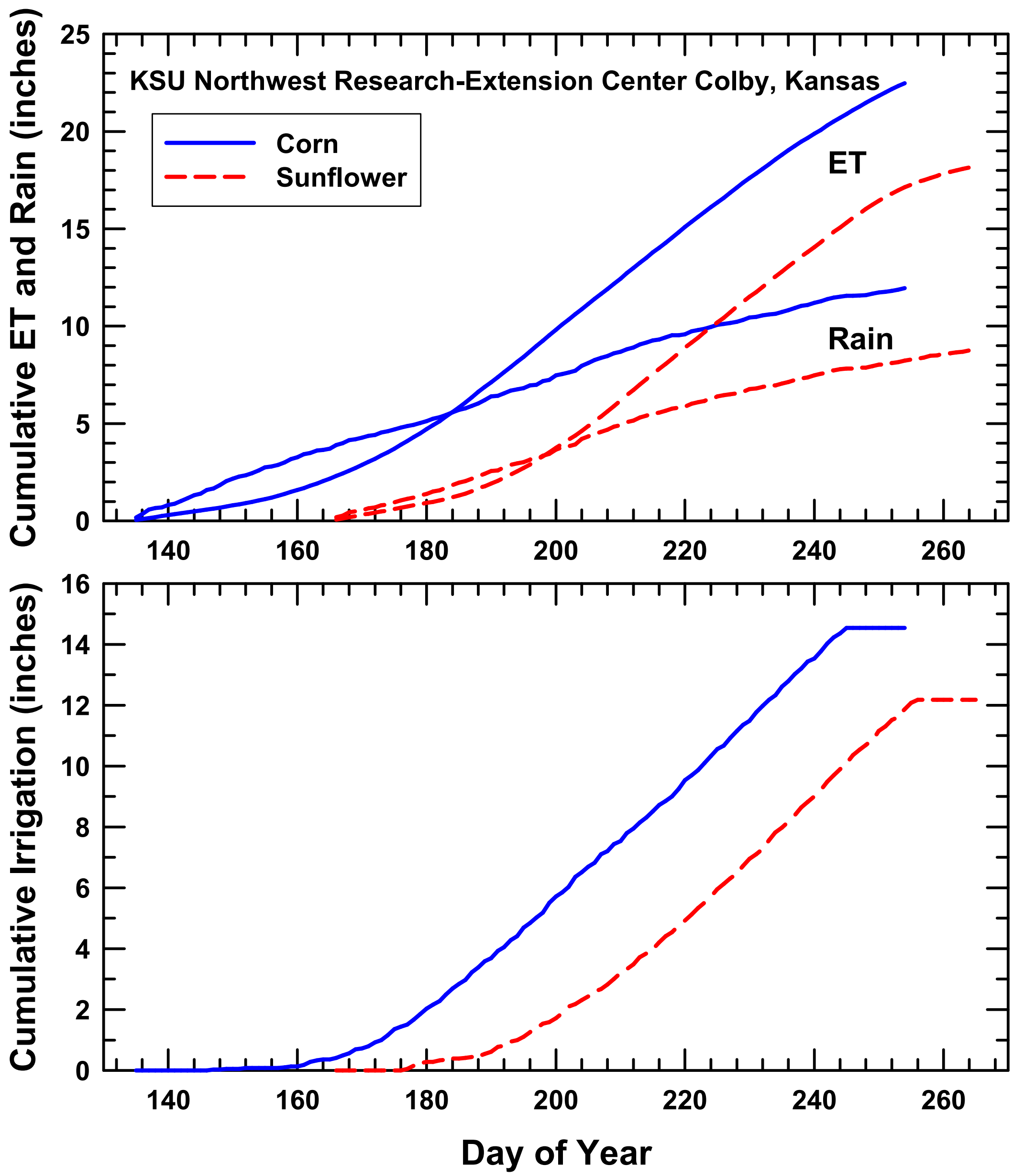

Figure 3. Simulated average cumulative crop water use (ET), rainfall and gross irrigation requirement for sunflower and corn for the 39 year period 1972 through 2010 at Colby, Kansas. Irrigation scheduling simulations were performed for sprinkler irrigation amounts of 1 inch at an application efficiency of 95%.

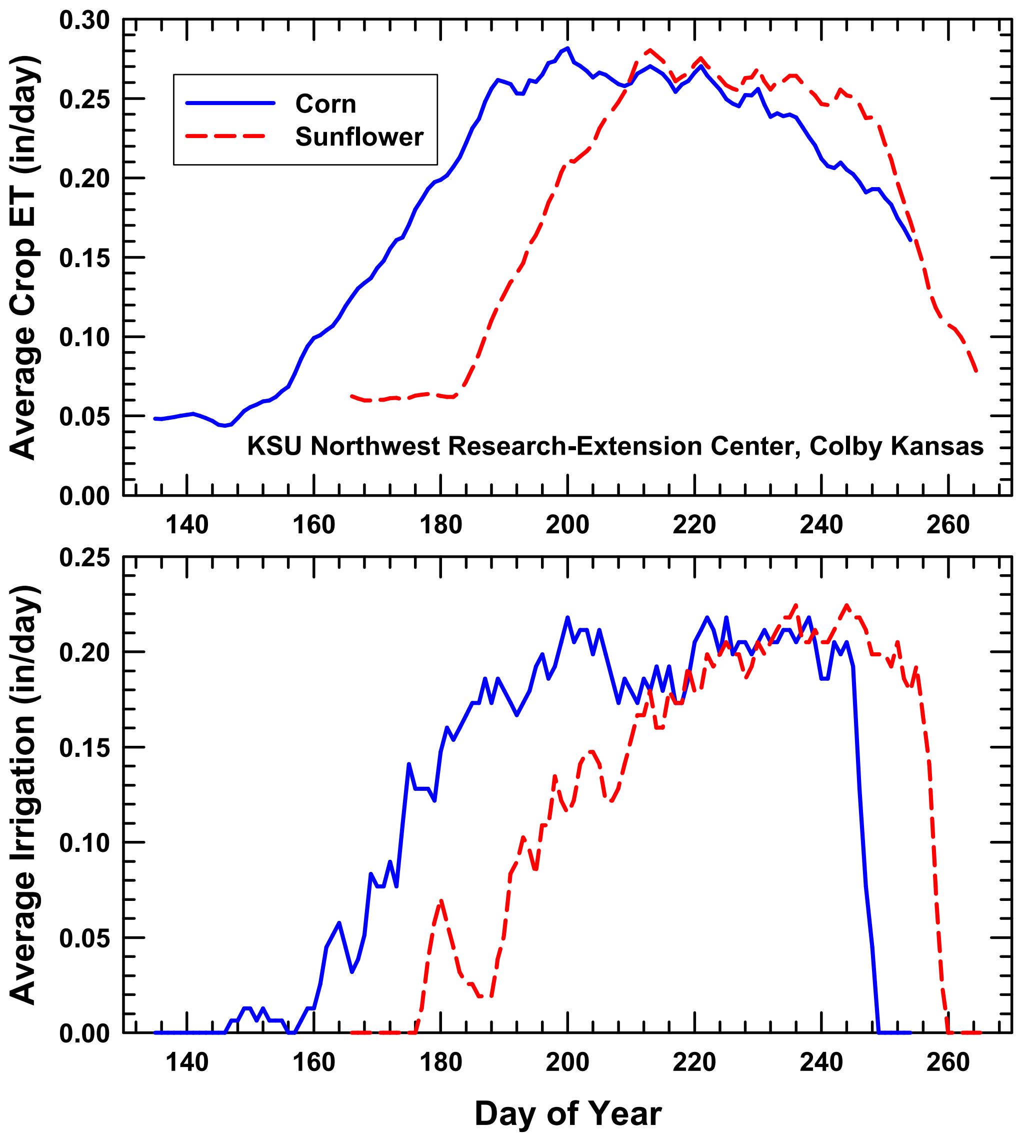

Figure 4. Simulated average daily crop water use (ET) and gross irrigation requirements for sunflower and corn for the 39-year period 1972 through 2010 at Colby, Kansas. Irrigation scheduling simulations were performed for sprinkler irrigation amounts of 1 inch at an application efficiency of 95%. The data are presented as a 4 day moving average.

The shorter duration of peak ET and irrigation needs for sunflower and their occurrence at a time when peak needs for corn are about to decline open up some opportunities to shift irrigation allocations between crops. Additionally, the yield decline with just slightly deficit irrigation is usually very small with sunflowers compared to corn (Figure 5). Under the right economics, sunflower can be a good candidate for deficit irrigation.

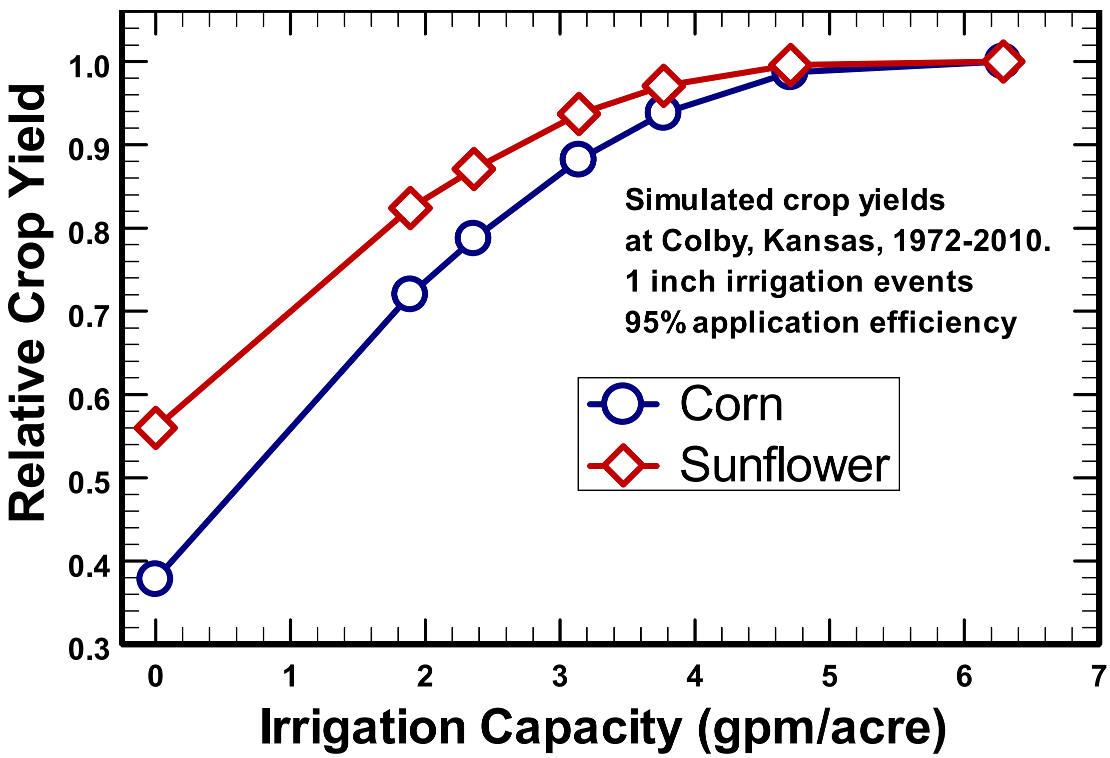

Figure 5. Simulated average relative crop yield of sunflower and corn as affected by irrigation capacity at Colby, Kansas for the 39-year period 1972-2010. Irrigation capacity data points left to right are dryland, 1 inch every 10, 8, 6, 5, 4 or 3 days, respectively. A capacity of 1 inch/4 days is equivalent to an irrigation capacity of 589 gpm/125 acre center pivot irrigation system.

As stated earlier, under full irrigation sunflower uses about 2.3 inches less irrigation than corn. However, because relative yield reductions are less for sunflower than with corn, many producers choose to deficit irrigate sunflowers and the annual irrigation difference may be 4 to 5 inches. Irrigation needs are greatest in August for sunflowers while the need is greatest in July for corn Figure 6. Some producers may want to plant a portion of their production area to sunflower to better manage their risk on lower capacity irrigation systems. However, they would be advised to estimate the economics of such a decision prior to the season. The Crop Water Allocator program (available at http://mobileirrigationlab.com/) developed by N.L Klocke and others at KSU can help with those decisions.

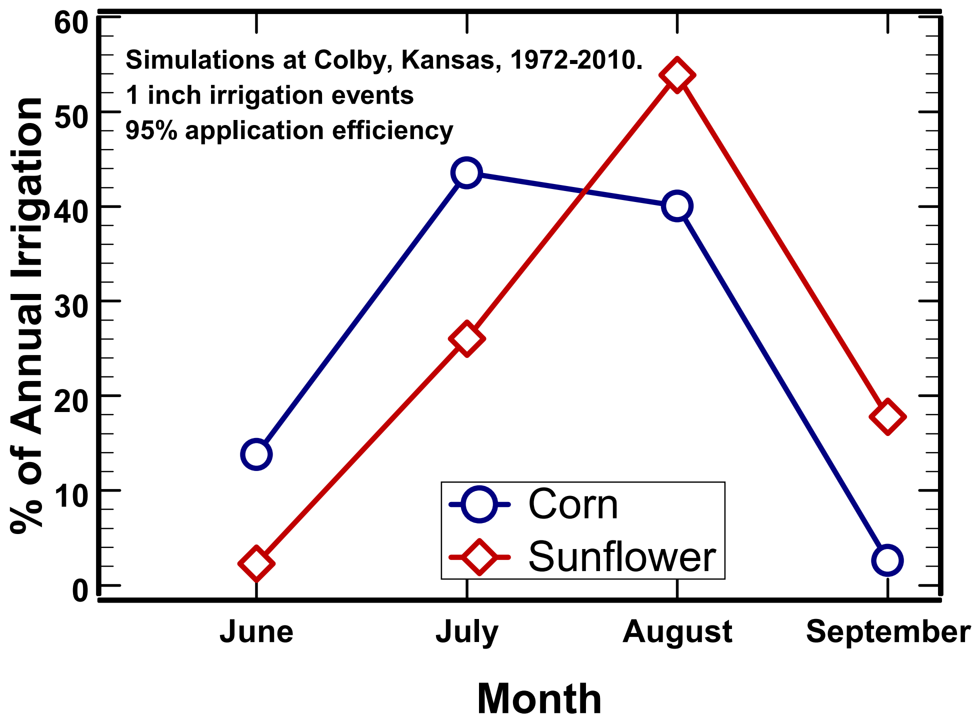

Figure 6. Average monthly distribution of irrigation needs of sunflower and corn at Colby, Kansas for the 39-year period 1972-2010 as determine from simulated irrigation schedules.

Summary

Research continues with developing irrigation strategies with sunflower in western Kansas. Declines in sunflower yield with deficit irrigation are less drastic than with corn, so producers may wish to consider sunflower when irrigation system capacities are marginal. Sunflower and corn have similar peak ET and irrigation rate requirements for full irrigation, but sunflower requires about 2.3 inches less irrigation and its peak needs began at about the time corn needs are starting to decline. Average full irrigation of sunflowers would be approximately 12 inches, but often producers will apply between 8 and 10 inches of irrigation because the amount of yield decline is only a few percentage points.

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