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Irrigated Sunflowers in Northwest Kansas: Productivity and Canopy Formation

F. Lamm
Kansas State University, flamm@ksu.edu

R. M. Aiken
Kansas State University, raiken@ksu.edu

A. A. AbouKheira
National Water Research Center, Barrage, Kaliobiya, Egypt

See next page for additional authors

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Irrigated Sunflowers in Northwest Kansas: Productivity and Canopy Formation

Abstract

Sunflower was grown in a three-year study (2009, 2010, and 2012) at the Kansas State University Northwest Research-Extension Center at Colby, KS, under a lateral move sprinkler irrigation system. Irrigation capacities were limited to no more than 1 inch every 4, 8, or 12 days but were scheduled only as needed as determined with a weather-based water budget. Achene (sunflower seed) yields and oil yield generally plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2% with most of this increase occurring in the extreme drought year, 2012. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/a.

Keywords

sunflower, irrigation, canopy

Cover Page Footnote

This work was partially supported by the Ogallala Aquifer Program administered by the U.S. Department of Agriculture Agricultural Research Service and by the National Sunflower Association. This article was originally published in the Proceedings of the 29th Annual Central Plains Irrigation Conference, Burlington, Colorado, Feb. 21-22, 2017.

Authors

F. Lamm, R. M. Aiken, A. A. AbouKheira, and G. J. Seiler

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F.R. Lamm, R.M. Aiken, A.A. AbouKheira, and G.J. Seiler

Summary

Sunflower was grown in a three-year study (2009, 2010, and 2012) at the Kansas State University Northwest Research-Extension Center at Colby, KS, under a lateral move sprinkler irrigation system. Irrigation capacities were limited to no more than 1 inch every 4, 8, or 12 days but were scheduled only as needed as determined with a weather-based water budget. Achene (sunflower seed) yields and oil yield generally plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2% with most of this increase occurring in the extreme drought year, 2012. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/a.

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.

Center pivot sprinkler irrigation (CP), the predominant irrigation method in the Ogallala region, presents unique challenges when used for deficit irrigation. Center pivot sprinkler irrigation cannot be effectively used to apply large amounts of water timed to a critical growth stage as can be done with surface irrigation methods. The CP systems also cannot efficiently use small, frequent events to alleviate water stress as is the case with subsurface drip irrigation (SDI). Thus, with CP systems, it is important that available soil water in storage be correctly managed temporally in terms of additions and withdrawals so that best crop production can be achieved both economically and water-wise. Three easy ways to control irrigation water additions are irrigation capacity, preseason management, and the season initiation date. Withdrawals can be partially managed by plant population. This study examined sunflower production using the three methods of controlling irrigation additions for three different targeted plant populations.

Procedures

The study was conducted from 2009 through 2012 at the Kansas State University Northwest Research-Extension Center (NWREC) at Colby, KS, under a lateral move sprinkler irrigation system. However, data from 2011 are excluded due to a devastating hail storm that destroyed the crop. Key agronomic characteristics of the annual tests are shown in Table 1.

Whole-plot treatments were sprinkler irrigation capacities of 1 inch every 4, 8, or 12 days as limited by evapotranspiration (ET)-based water budget irrigation scheduling. An additional whole-plot irrigation factor was the addition, or no addition, of dormant preseason irrigation, resulting in a total of 6 different irrigation treatments. The target preseason irrigation amount for those plots receiving this treatment was 5 inches, but in 2012 a total of 9.2 inches of preseason irrigation was applied due to an application error. Three targeted plant populations 18,000, 23,000, or 28,000 plants/a were superimposed on the whole plots for a grand total of 108 subplots. Irrigation amounts were 1 inch applied as needed, but limited by the imposed capacity and the water budget irrigation schedule. The whole plots (6 repetitions) were in a randomized complete block design.

Soil water was measured periodically in each plot each crop season with a neutron probe to a depth of 8 feet in one foot increments. Crop water use was calculated as the sum of changes in soil water between emergence and physiological maturity, precipitation and irrigation amount. Crop water productivity (WP, also known as water use efficiency) was calculated as the achene yield in lb/a divided by the total crop water use in inches.

At R6 development stage and to maturity (R9 development stage), sunflower achene moisture content, dry mass, and oil content were measured by collecting six achenes from each of five representative plants, semi-weekly. At maturity, sunflower heads were hand harvested from a representative sample area and threshed for yield and yield component.

Leaf area index (LAI) was quantified, approximately bi-weekly, by a non-destructive light transmission technique (Welles, 1991; LAI-2000 Plant Canopy Analyzer; Li-Cor, Lincoln, NE). Three sets of four below-canopy measurements were each referenced to an above-canopy measurement, minimizing sensor exposure to direct (beam) irradiance. Readings were screened against apparent transmittance ratios exceeding 1 using the manufacturer's software, FV2000 (Li-Cor, Lincoln, NE). An inverse solution to a model of light transmission through a vegetative canopy, provided by the manufacturer, was used to quantify apparent LAI.

Growing degree days (GDD) were calculated from daily temperature extremes (Equation 1) recorded at the NWREC weather station, using a mercury thermometer.

$$GDD = \frac{T_{max} - T_{min}}{2} - T_b \qquad \textit{Equation 1}$$

Upper and lower limits to temperature extremes were 34°C and 4°C (93°F and 39°F), respectively. Cumulative GDD (cGDD) was computed by summation of GDD, commencing from planting date.

Statistical analysis used analysis of variance (ANOVA) and analysis of covariance (ANCOVA). Repeated measure of LAI and maximum LAI observed in a year were analyzed by ANOVA, using Proc GLM from SAS 9.4 (SAS Institute Inc., Cary, NC). Seasonal trends in LAI were analyzed by ANCOVA using third-order linear terms of cGDD or days after planting (DAP) as covariates.

Results

Weather Conditions

The crop year 2009 was very cool and wet and irrigation needs were low. In-season irrigation amounts for the 1 inch every 4, 8, and 12 days' treatments were 7.68, 6.72, and 4.80 inches, respectively. During the period April through October, every month had above-normal precipitation and between crop emergence and crop maturity the total precipitation was 9.89 inches.

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. Precipitation during the sunflower growing period totaled 7.32 inches. In-season irrigation amounts were 11.52, 6.72, and 4.8 inches for the irrigation capacities limited to 1 in./4 d, 1 in./8 d, and 1 in./12 d, respectively. The 2010 sunflower irrigation amounts appear to be approximately 1 inch less than normal as estimated from long term (1972-2005) irrigation scheduling simulations conducted at Colby, KS.

Extreme drought conditions existed for all of 2012, and only 5.25 inches of precipitation occurred during the sunflower growing period. Additionally, temperatures of 100°F or greater occurred on 20 days between June 26 and August 15. Crop establishment may have been negatively affected by excessively hot temperatures (99 to 104°F) that occurred for the entire period between planting and emergence even though small amounts of irrigation kept sufficient amounts of water in the seed zone. Sunflower plant populations at harvest in 2012 averaged approximately 75% of levels that occurred in 2009 and 2010. In-season irrigation amounts were 13.94, 8.18, and 6.26 inches for the irrigation capacities limited to 1 in./4 d, 1 in./8 d, and 1 in./12 d, respectively.

Summarizing the weather conditions, the crop year 2009 was cooler and wetter than normal, the crop year 2010 was approximately normal, though a severe drought began in early August, and the crop year 2012 was extremely hot and dry.

Crop Yields and Yield Components

The addition of dormant preseason irrigation did not significantly increase yields in any of the three years (Tables 2, 3, and 4), but it did increase achene yield and oil yield by 2%, when all years were analyzed together. Most of the increase in yield for preseason irrigation occurred in the extreme drought year, 2012. Preseason irrigation did significantly increase heads per plant in 2009 and harvest plant population in 2010, but these differences were only about 3% greater. There were no statistically significant differences in yield attributable to irrigation capacity in 2009 and 2012, but increased irrigation capacity did increase achene yield in 2010. Increased irrigation capacity tended to numerically increase achene and oil yield in all three years up through the 1 in./8 d irrigation capacity but tended to have less or no response above that level (Figure 1). Achene yields were lower in 2010 than in 2009 and 2012, but still were towards the upper range of yields for the region.

There were no plant population effects on achene yield in 2009, but increased plant population decreased achene yield in 2010 and increased achene yield in 2012 (Tables 2, 3, and 4). The difference between 2010 and 2012 responses is probably related to the differences in harvest plant populations between the two years. As indicated in earlier section, crop establishment was poor in 2012. Harvest plant populations in 2010 averaged 19,263, 23,426, and 26,257 plants/a for the three respective targets as compared to the much lower 2012 values of 14,452, 17,530, and 19,781 plants/a. Increasing plant population significantly decreased achenes/head in both 2009 and 2010 but had no consistent effect in 2012, once again probably because harvest plant populations were so low (Tables 2, 3, and 4). Increasing plant population significantly decreased achene mass and significantly increased achene oil content (percentage) in all three years. Within a given year average differences in oil content ranged from 1 to 2% as affected by plant population. Harvest plant populations above 19,000 to 20,000 plants/a resulted in reduced achene yields and oil yields, but oil content was greatest at the greatest plant population in all three years (Figure 2).

Crop Water Use and Water Productivity

In-season crop water use was significantly greater due to increased irrigation in all three years (Tables 2, 3, and 4, and Figure 1). However, crop water productivity (WP) was significantly reduced by increased irrigation in all three years. Irrigation amounts ranged from 4.80 to 7.68 inches in 2009, 4.80 to 11.52 inches in 2010, and 6.26 to 13.94 inches in 2012. Soil water depletion decreased with irrigation capacity (data not shown).

Canopy Formation

Seasonal changes in sunflower canopy are shown in Figure 3. Preseason irrigation amounts of 9 inches resulted in greater leaf area from mid-vegetative growth through mid-seed fill in 2012. Canopy formation and senescence occurred relatively earlier in 2010 than 2009 and 2012, which were similar. Canopy formation was greatest in 2010 and least in 2012.

Yield Formation

Achene water content, oil content, and dry mass changes during the season are shown in Figure 4. Achene water contents were greatest for the initial sampling dates and declined throughout the seed fill period. In 2010, achene water content was slightly greater for the largest irrigation capacity. Oil content of achenes increased from the R6 to R8 development stage, remaining consistent through maturity; slightly greater oil contents were observed for the smallest irrigation capacity in 2010. Oil contents from late-season samples appeared similar, though the harvest samples from a larger sampling area (Tables 2, 3, and 4) indicate greatest oil content in 2009 (46.0%) and smallest oil content in 2012 (39.9%). The change in achene mass in 2012, relative to the initial sampling date, was approximately twice the amount than what was observed in 2009 and 2010; this likely reflected effects of the reduced stands discussed earlier. Preseason irrigation resulted in larger achenes in 2009, but smaller achenes in 2012, likely reflecting differences in achenes per head. Cumulative growing degree days appear to provide an inconsistent measure of time relative to onset and completion of the yield formation periods, as indicated by the staggered onset and duration of sampling intervals over the three growing seasons (Figure 4).

Conclusion

Sunflower was grown under sprinkler irrigation in Colby, KS, for three very different crop years (2009, cool and wet year; 2010, near normal overall but very dry after flowering; and 2012, severe drought year with high temperatures). Irrigation capacities were limited to not more than 1 inch every 4, 8, or 12 days, but irrigation events were scheduled only as needed as determined with a weather-based water budget. Seasonal trends indicated earlier canopy formation, greatest canopy extent, and earliest senescence in 2010; least canopy extent developed in 2012. Seasonal trends were similar for achene water content (decreasing through maturity), oil content, and achene mass (increasing through R8 development stage). Achene yield was only statistically increased by irrigation in 2010, but tended to increase numerically up through the medium irrigation level (1 in./8 d) in all three years. Similarly, oil yield plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2%. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/a.

Acknowledgements

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Table 1. Agronomic characteristics of an irrigated sunflower study conducted at the Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012[1]

Characteristic	2009	2010	2012
Hybrid	Triumph S671	Triumph S671	Triumph S671
Planting date	June 18	June 16	June 13
Emergence date	June 25	June 24	June 26
Harvest date	October 16	October 13	October 8
Rainfall, emergence to maturity (inches)	9.89	7.32	5.25
Preseason irrigation (inches)	5.0	5.0	9.2
First seasonal irrigation	July 27	July 25	July 25
Last seasonal irrigation	September 15	September 15	September 23

[1]Data from 2011 are excluded due to devastating hail storm.

Table 2. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2009, Kansas State University Northwest Research-Extension Center, Colby, KS

Irrigation capacity	Preseason irrigation	Targeted plant population	Yield	Harvest plant population	Heads /plant	Achenes /head	Achene mass	Achene oil	Water use	Water productivity
		1,000 p/a	lb/a	p/a			mg	%	in.	lb/a, in.
1 in/4 d (7.68 in.)	None	18	3,266	16,262	0.94	2,114	46.6	45.6	21.94	149
		23	3,324	20,183	0.92	2,043	40.2	46.2	22.49	148
		23	3,109	23,813	0.93	1,720	37.2	46.6	22.10	141
		Mean	3,233	20,086	0.93	1,959	41.3	46.2	22.18	146
	5 inches	18	3,229	16,553	0.94	2,155	44.3	45.7	22.06	146
		23	3,326	20,328	0.93	1,919	42.0	46.3	22.24	150
		28	3,246	22,942	0.99	1,728	39.3	46.8	22.96	141
		Mean	3,267	19,941	0.95	1,934	41.9	46.2	22.42	146
Mean 1 inch/4 days			3,250	20,013	0.94	1,947	41.6	46.2	22.30 c	146 b
1 in/8 d (6.72 in.)	None	18	3,376	16,698	0.95	2,259	43.4	45.7	21.08	161
		23	3,189	20,183	0.95	1,893	40.4	46.0	21.29	150
		23	3,081	22,506	0.96	1,790	37.5	46.5	21.89	141
		Mean	3,215	19,796	0.95	1,981	40.4	46.1	21.42	151
	5 inches	18	3,427	16,553	0.99	2,214	42.8	45.0	21.56	159
		23	3,208	19,312	0.96	1,934	40.6	46.1	21.21	151
		28	3,332	22,506	1.01	1,766	38.4	46.6	22.01	152
		Mean	3,322	19,457	0.99	1,971	40.6	45.9	21.60	154
Mean 1 inch/8 days			3,269	19,626	0.97	1,976	40.5	46.0	21.51 b	152 a
1 in/12 d (4.80 in.)	None	18	3,158	16,408	0.93	2,198	42.8	45.7	20.38	155
		23	3,186	19,457	0.96	1,923	40.3	45.9	20.75	154
		23	3,168	24,103	0.91	1,728	38.3	46.5	20.75	153
		Mean	3,171	19,989	0.93	1,950	40.5	46.0	20.63	154
	5 inches	18	3,100	16,117	0.97	2,127	42.3	46.1	20.36	152
		23	3,345	19,166	0.96	1,985	41.9	45.6	20.41	164
		28	3,279	23,522	0.94	1,758	38.4	46.2	20.68	159
		Mean	3,241	19,602	0.96	1,957	40.8	45.9	20.48	158
Mean 1 inch/12 days			3,206	19,796	0.95	1,953	40.7	46.0	20.56 a	156 a
Study-wide mean			3,242	19,812	0.95	1,959	40.9	46.0	21.45	151
Preseason irrigation	None		3,206	19,957	0.94 a	1,963	40.7	46.1	21.41	150
	5 inches		3,277	19,667	0.97 b	1,954	41.1	46.0	21.50	153
Target plant population (1000 p/a)		18	3,260	16,432 a	0.95	2,178 a	43.7 a	45.6 c	21.23 a	154 a
		23	3,263	19,771 b	0.95	1,950 b	40.9 b	46.0 b	21.40 a	153 a
		28	3,203	23,232 c	0.96	1,748 c	38.2 c	46.5 a	21.73 b	148 b

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower-cased letter.

Table 3. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2010, Kansas State University Northwest Research-Extension Center, Colby, KS

Irrigation capacity	Preseason irrigation	Targeted plant population	Yield	Harvest plant population	Heads /plant	Achenes /head	Achene mass	Achene oil	Water use	Water productivity
		1,000 p/a	lb/a	p/a			mg	%	in.	lb/a, in.
1 in/4 d (11.52 in)	None	18	3,172	20,038	0.94	1,916	40.4	44.2	22.69	141
		23	2,919	23,668	0.89	1,631	38.6	44.7	22.74	128
		28	2,946	27,007	0.85	1,570	37.4	45.0	23.32	127
		Mean	3,012	23,571	0.90	1,706	38.8	44.6	22.92	132
	5 inches	18	3,000	19,166	0.93	1,845	42.3	43.8	20.99	143
		23	3,062	23,958	0.95	1,646	37.3	44.7	21.15	146
		28	2,987	25,265	0.95	1,597	36.1	45.3	20.72	145
		Mean	3,172	20,038	0.94	1,916	40.4	44.2	22.69	141
Mean 1 inch/4 days			3,014 a	23,184	0.92	1,701	38.7	44.6 a	21.93 a	138 c
1 in/8 d (6.72 in)	None	18	3,043	19,602	0.92	1,893	41.0	44.5	19.63	157
			2,989	23,377	0.98	1,668	36.1	44.6	20.01	150
			3,004	25,700	0.97	1,563	35.7	45.3	19.36	156
			3,012	22,893	0.96	1,708	37.6	44.8	19.66	154
	5 inches	18	3,091	18,440	0.98	1,912	40.6	44.3	19.01	164
			2,892	23,087	0.93	1,647	37.2	44.7	19.31	151
			2,951	25,410	0.98	1,506	36.3	45.3	19.58	152
			3,043	19,602	0.92	1,893	41.0	44.5	19.63	157
Mean 1 inch/8 days			2,995 a	22,603	0.96	1,698	37.8	44.8 a	19.48 b	155 b
1 in/12 d (4.80 in)	None	18	2,983	19,312	0.96	1,868	39.4	43.2	17.25	175
			2,886	23,522	0.96	1,715	34.4	43.6	16.85	175
			2,705	27,588	0.88	1,480	34.4	44.0	17.10	159
			2,858	23,474	0.93	1,688	36.1	43.6	17.07	170
	5 inches	18	3,059	19,021	0.95	1,983	39.0	43.7	18.12	170
			2,831	22,942	0.94	1,613	37.0	43.6	17.99	158
			2,833	26,572	0.91	1,511	35.5	44.1	17.67	162
			2,908	22,845	0.93	1,702	37.2	43.8	17.93	163
Mean 1 inch/12 days			2883 b	23,159	0.93	1,695	36.6	43.7 b	17.50 c	167 a
Study-wide mean			2,964	22,982	0.94	1,698	37.7	44.4	19.64	153
Preseason irrigation	None		2,961	23,313 a	0.93	1,700	37.5	44.3	19.88	152
	5 inches		2,967	22,651 b	0.95	1,695	37.9	44.4	19.39	155
Target plant population (1000 p/a)		18	3,058 a	19,263 c	0.94	1,903 a	40.5 a	43.9 c	19.61	158 a
		23	2,930 b	23,426 b	0.94	1,653 b	36.8 b	44.3 b	19.67	151 b
		28	2,904 b	26,257 a	0.92	1,538 c	35.9 b	44.8 a	19.62	150 b

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower-cased letter.

Table 4. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2012, Kansas State University Northwest Research-Extension Center, Colby, KS

Irrigation capacity	Preseason irrigation	Targeted plant population	Yield	Harvest plant population	Heads /plant	Achenes /head	Achene mass	Achene oil	Water use	Water productivity
		1,000 p/a	lb/a	p/a			mg	%	in.	lb/a, in.
1 in/4 d (13.94 in.)	None	18	3,145	14,956	1.00	1,555	61.6	39.4	24.82	126
			3,265	16,988	0.99	1,497	59.6	39.8	25.89	126
			3,315	21,635	0.87	1,750	52.9	41.6	24.86	133
			3,242	17,860	0.95	1,601	58.0	40.3	25.19	129
	9.2 inches	18	3,183	14,985	1.00	1,666	58.1	39.1	25.33	126
			3,448	17,424	0.99	1,572	58.2	40.3	25.64	134
			3,662	19,689	0.99	1,599	53.7	40.3	26.79	137
			3,431	17,366	0.99	1,612	56.6	39.9	25.92	132
Mean 1 inch/4 days			3,328	17,635	0.97	1,606	57.4	40.1	25.52 a	130 c
1 in/8 d (8.18 in.)	None	18	3,191	13,939	1.00	1,717	62.6	38.9	20.45	157
			3,160	16,698	0.99	1,494	58.8	39.6	20.23	156
			3,423	19,747	1.00	1,439	55.3	40.8	20.80	165
			3,258	16,795	1.00	1,550	58.9	39.7	20.49	159
	9.2 inches	18	3,148	14,375	1.00	1,544	65.2	39.2	18.61	172
			3,310	17,569	0.98	1,495	59.4	40.1	18.37	181
			3,480	19,747	1.00	1,414	58.0	41.5	18.75	187
			3,313	17,230	0.99	1,484	60.9	40.3	18.58	180
Mean 1 inch/8 days			3,286	17,013	0.99	1,517	59.9	40.0	19.54 b	169 b
1 in/12 d (6.26 in.)	None	18	3,237	14,462	1.00	1,610	63.8	39.1	17.41	188
			3,126	17,772	0.98	1,280	64.9	39.9	17.18	183
			3,121	18,121	1.00	1,490	54.5	40.0	17.43	180
			3,161	16,785	0.99	1,460	61.0	39.7	17.34	183
	9.2 inches	18	3,074	14,084	1.00	1,440	70.1	38.4	18.52	168
			3,487	18,992	0.99	1,478	57.5	39.8	18.47	191
			3,417	19,457	0.97	1,410	59.3	40.5	18.47	186
			3,316	17,424	0.99	1,440	62.6	39.5	18.49	181
Mean 1 inch/12 days			3,244	17,125	0.99	1,450	61.9	39.6	17.95 c	182 a
Study-wide mean			3,286	17,251	0.99	1,525	59.7	39.9	20.99	161
Preseason irrigation	None		3,224	17,168	0.98	1,541	59.2	39.9	21.22	156
	9.2 inches		3,350	17,337	0.99	1,508	60.2	39.9	20.75	166
Target plant population (1000 p/a)		18	3,160 b	14,452 c	1.00	1,586	63.7 a	39.0 c	20.83	156
		23	3,294 ab	17,530 b	0.99	1,472	59.7 b	39.9 b	21.01	161
		28	3,404 a	19,781 a	0.97	1,515	55.7 c	40.8 a	21.13	165

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower-cased letter.

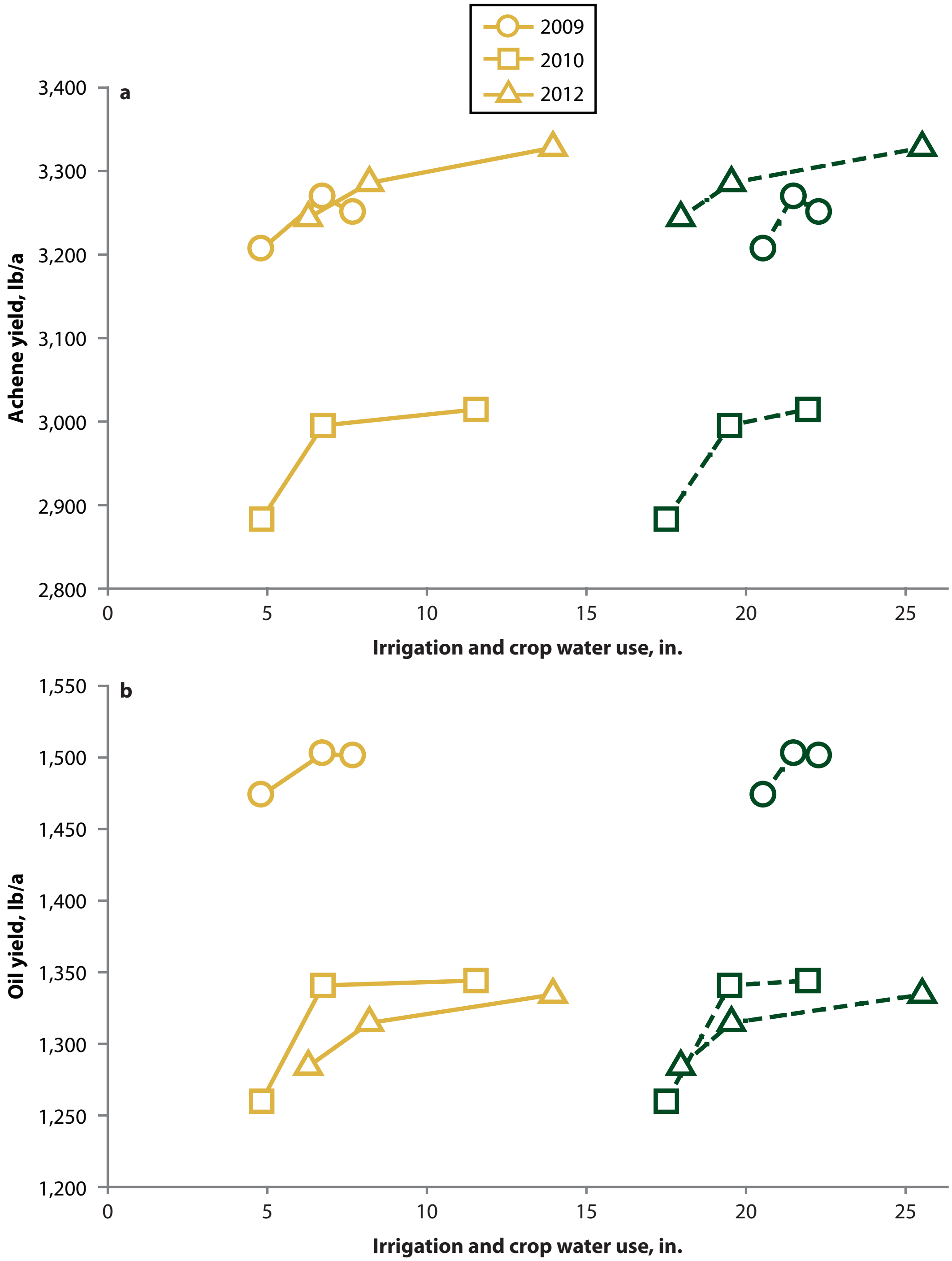

Figure 1. Achene yield and oil yield as related to irrigation amount and total crop water use in a sprinkler irrigated sunflower study, Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012. Irrigation responses are in yellow unbroken lines and crop water use responses in green dashed lines.

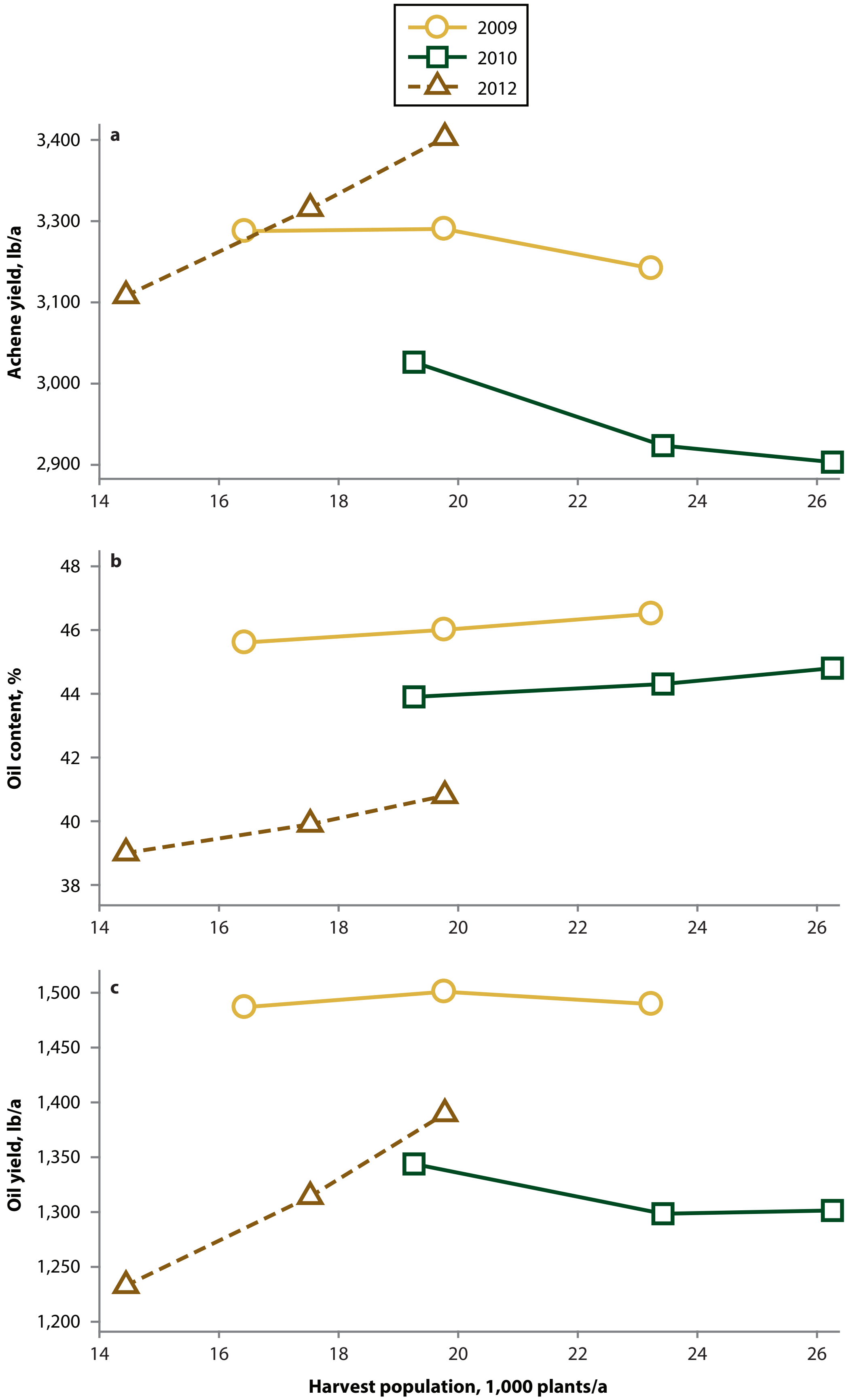

Figure 2. Achene yield, oil content, and oil yield as related to harvest plant population in a sprinkler irrigated sunflower study, Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012.

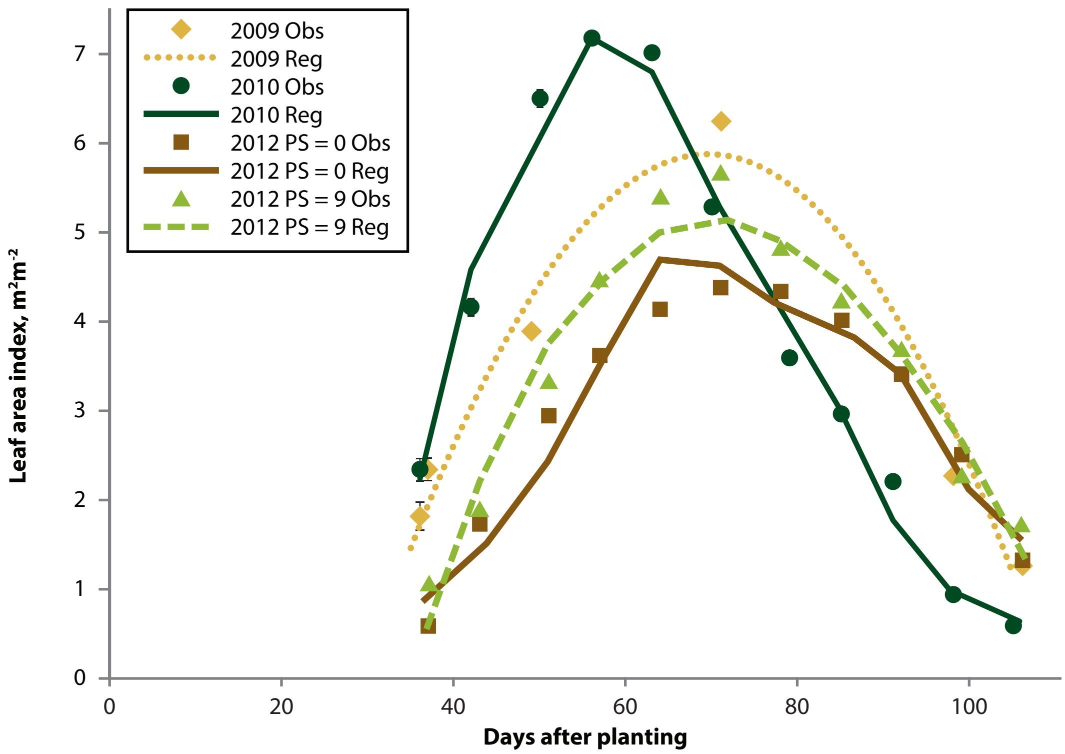

Figure 3. Seasonal trends in canopy formation and senescence are shown in relation to days after planting for a sprinkler irrigated sunflower study, Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012. Note that symbols represent field observations and lines represent a trend model. Preseason irrigation effects (0 or 9 inches) were detected in 2012.

[1] Mention of tradenames is for informational purposes only and does not constitute endorsement by the authors or by the institutions they serve.