Sunflower canopy and oilseed yield formation under deficit irrigation

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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. 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.

Methods and Materials

The plot area was planted to a short stature Triumph hybrid S671 on June 18, 2009 and June 16, 2010; soil fertility was supplemented for a 3000 lb/A yield goal. Whole plot treatment sprinkler irrigation capacities of 1 inch every 4, 8 or 12 d limited by ET-based water budget irrigation scheduling were used with irrigation to start as early as July 1 or as late as July 20. The purpose of differences in starting date was to gain information for management of sprinklers where crop type is split within the irrigated area (such as when the critical needs for corn are earlier than sunflower). An additional whole plot irrigation treatment was the addition or no addition of 5 inches of dormant season irrigation in early May resulting in a total of 12 different irrigation treatments. Three plant populations 18,000, 23,000 or 28,000 pl/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 (3 reps) were in a randomized complete block design with irrigation applied using a lateral move sprinkler. Sunflower canopy temperatures were measured for the highest and lowest capacities (1 inch/4 days and 1 inch/12 days) for plots with a starting date of July 1 for both those receiving and not receiving preseason irrigation (4 trts x 3 reps for 12 total plots). Deficit irrigation effects on canopy formation were determined by repeated measure of light transmittance (LiCor Plant Canopy Analyzer). Seed fill-rate, oil content and fatty acid composition were determined from bi-weekly samples. Crop water use was determined by the soil water balance method using neutron thermalization and irrigation records. A photothermal quotient (MJ $^{o}C^{-1}$) was calculated from the ratio of daily solar radiation and growing degree day (4 ^{o}C base temperature), averaged over the interval 30 days prior to and 20 days following the onset of flowering (R5.0). Irrigation and seeding rate effects were analyzed in relation to days after planting or cumulative growing degree days using analysis of covariance in Proc GLM of SAS v 9.13.

Results

Maximum canopy coincided with the onset of anthesis in cool (2009) and normal (2010) growing seasons (Fig. 1). In a cool season (2009) canopy formation was greatest for intermediate populations (23,000 pl/A) relative to smaller (18,000 pl/A) and larger (28,000 pl/A) populations; no differences were detected in 2010. Mature seed numbers (9,160 seeds m^{-2}, 2009; 9,030, seeds m^{-2}, 2010) were slightly less than that predicted from a photothermal quotient (10,800 seeds m^{-2}, Cantagallo et al., 1997). Seed fill rates (0.9 to 1.2 mg day^{-1}), maximum seed mass (37 - 45 mg), oil content (43.9% - 46.5%) and oilseed yields (3.2 - 3.6 Mg ha^{-1}; 2,860 - 3,200 lb/A) were favored by cooler growing conditions. Seed fill rates occurred primarily during R6-R8 reproductive stages and coincided with a linear decline in seed moisture, relative to days after flowering (Fig. 2). Maximum seed mass was favored by increased irrigation capacity (0.08 - 0.25 inch/day) when no pre-season irrigation (5 inches) was applied in 2010, a representative growing season. Oil content and oil yield increased with seeding rates in both growing seasons (not shown). Water use (440 - 510 mm; 17.3 - 20.0 inches) was reduced for the cooler growing season (Fig. 3). Fatty acid composition of oil indicated seasonal trends which were affected by irrigation management, e.g. oleic fraction decreased and linoleic fraction increased with pre-season irrigation (5 inches) in 2009, a cool and wet growing season (Fig. 4).

Summary

Maximum canopy formation coincided with onset of flowering (R5.0); canopy cover was incomplete during late seed-fill. Mature seed number was slightly less than predictions of a photothermal quotient model. Oilseed productivity was favored by cooler growing conditions and water sufficiency. Oil content and oil yield increased with seeding rates. Fatty acid composition exhibited seasonal trends in relation to thermal time, with moderate effects of irrigation management.

References

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Acknowledgements

This research was funded by the Kansas Agricultural Experiment Station, National Sunflower Association and Ogallala Aquifer Program, a consortium among USDA-Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

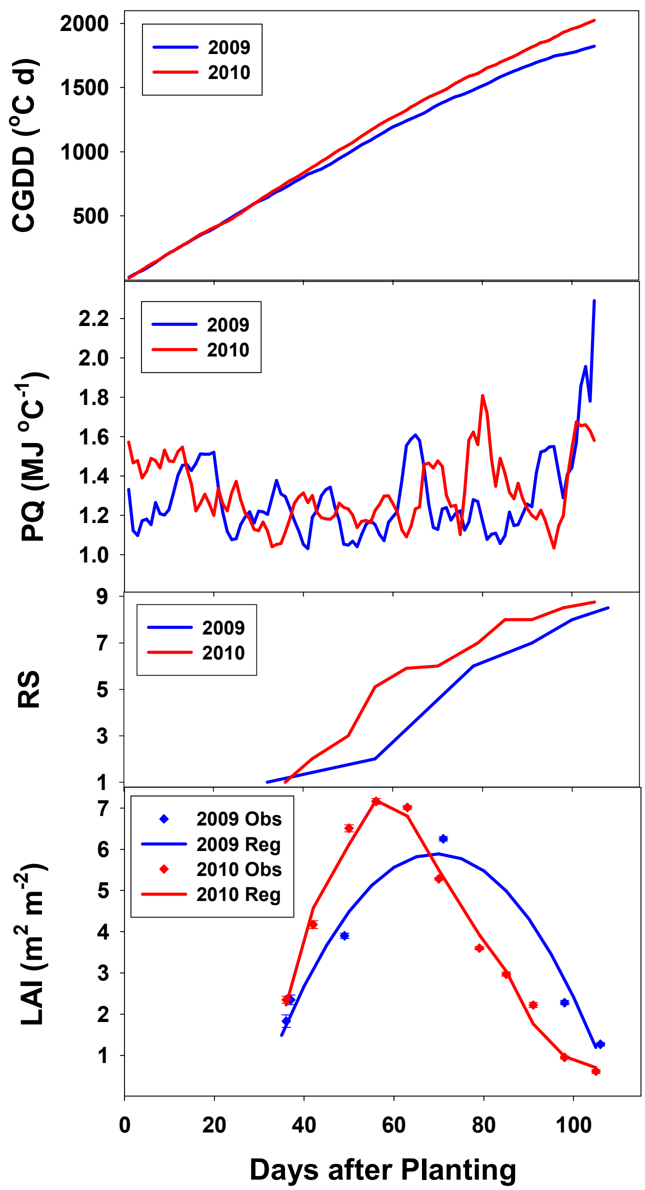

Figure 1. Leaf area index (LAI), sunflower reproductive stage (RS, Schneiter and Miller, 1981), photothermal quotient (PQ, five-day running average) and cumulative growing degree days (CGDD) are shown in relation to days after planting (DAP). Cooler growing conditions, in 2009, commencing 40 DAP, corresponded with delayed canopy formation and reproductive development. Average PQ, 30 days prior to and following the onset of flowering (RS 5.0), was similar in both years (1.22).

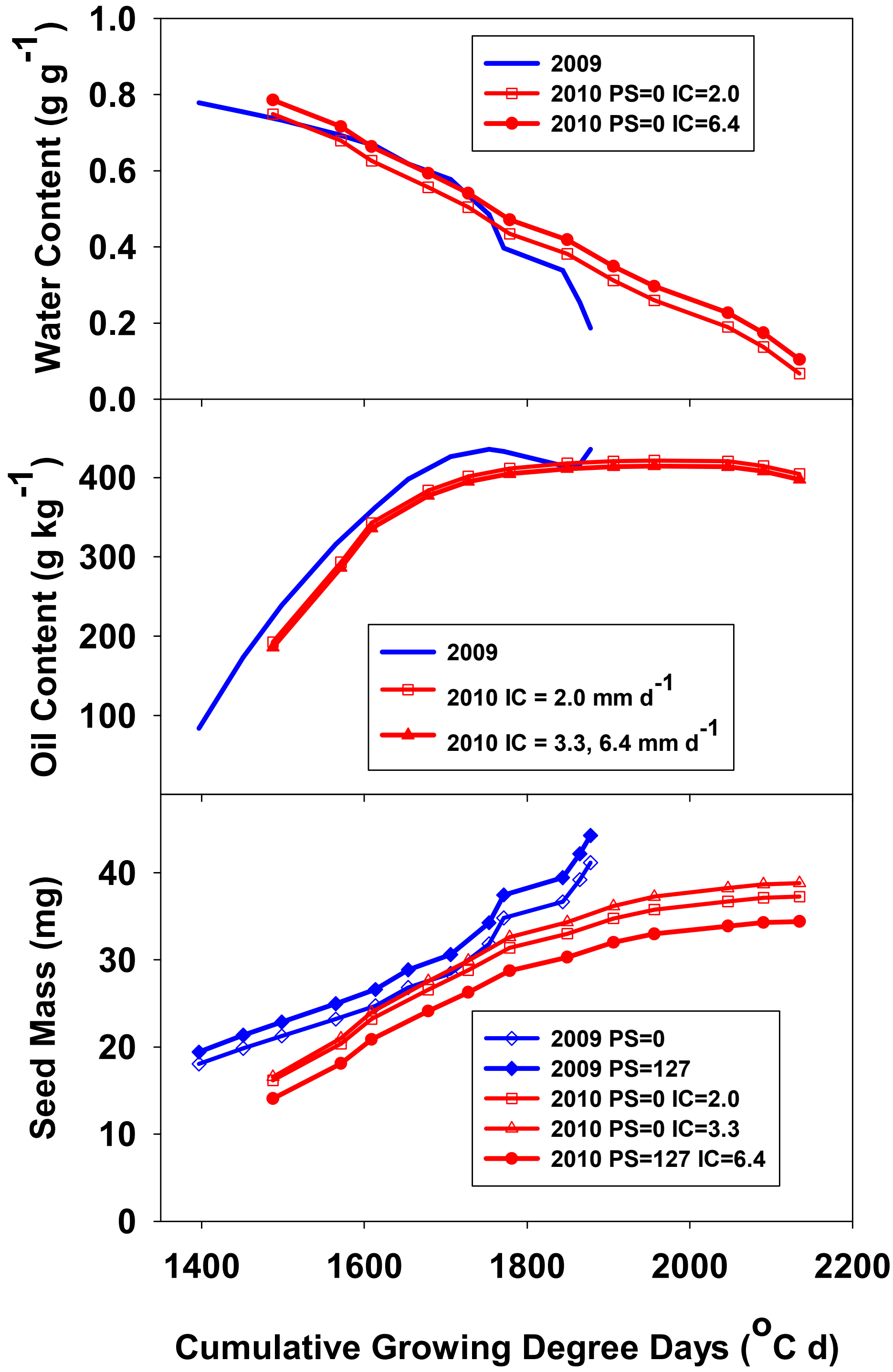

Figure 2. Seed mass, oil content and water content are shown in relation to cumulative growing degree days after planting. Seed water content decreased in linear relation to days after flowering (not shown); oil content approached maximum at approximately 1700 ^{o}Cd (RS 8); seed fill rate was favored by cool conditions in 2009.

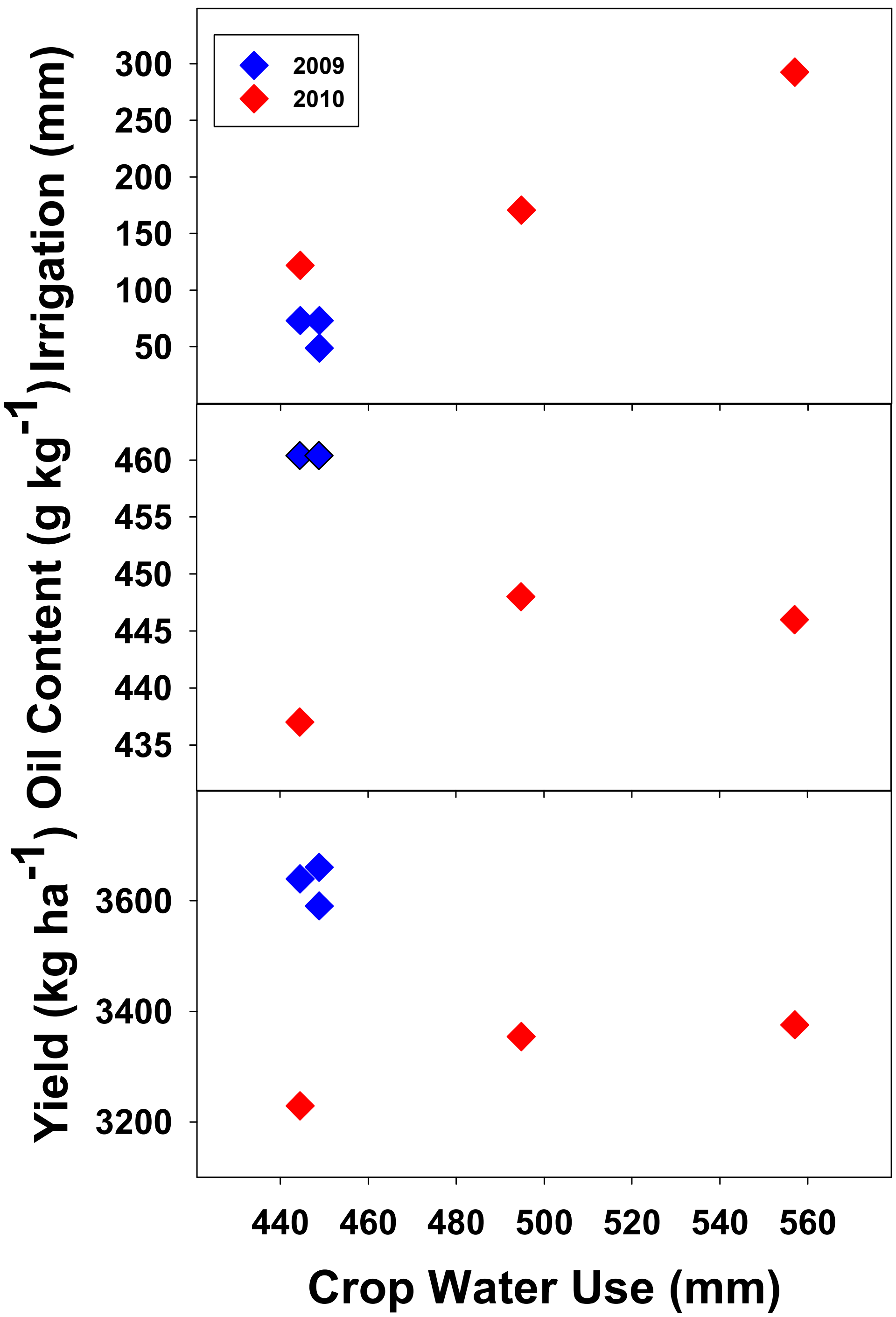

Figure 3. Oilseed sunflower yield, oil content and irrigation amounts are shown in relation to crop water use, resulting from irrigation capacities of 0.08, 0.125 or 0.25 inch/day. Limited irrigation was required to replace evaporative demand in 2009, a cool and wet growing season. Deficit irrigation reduced yields, but increased water productivity in 2010, representing typical growing conditions.

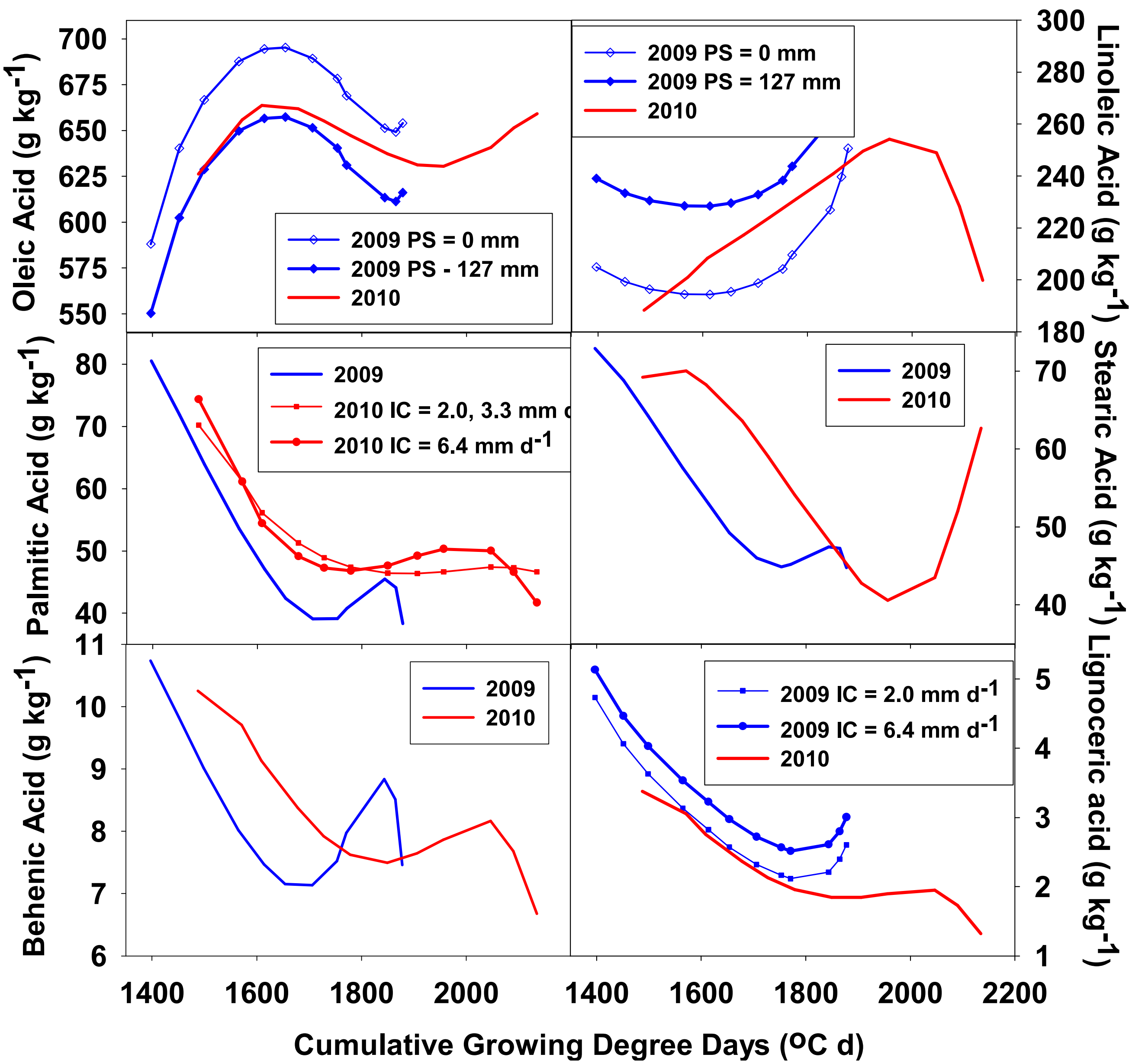

Figure 4. Fatty acid composition of oil is shown in relation to thermal time after planting. Seasonal trends in composition appear to correspond to thermal time for all components with exception of behenic acid, which appears to correspond more closely to calendar days (not shown). Pre-season irrigation reduced oleic fraction and increased linoleic fraction in 2009, a cool and wet year. Irrigation capacity altered palmitic fraction in 2010 and lignoceric fraction in 2009.