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Effect of Early Season Water Stress on Corn in Northwest Kansas

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***Abstract*.** Decisions about when to initiate the irrigation season is an important irrigation macromanagement decision that can potentially save water and increase net income when made correctly, but can have negative economic consequences when made incorrectly. A combination of nine years of pre-anthesis water stress studies for corn was conducted at the Kansas State University Northwest Research-Extension Center in Colby, Kansas on a productive, deep, silt loam soil. Overall, the pre-anthesis water stress studies suggest that corn grown on this soil type has great ability to handle early-season water stress, provided the water stress can be relieved during later stages. A critical factor in maximizing corn grain yields as affected by pre-anthesis water stress is maximizing the kernels/area. Maintaining a water deficit ratio (well-watered calculated corn water use / sum of irrigation and precipitation) greater than 0.7 to 0.8 or limiting available soil water depletion in the top 4 ft of soil profile to approximately 30% maximized the kernels/area. Some of these results contradict traditional irrigation guidelines.

Keywords. Irrigation management, water stress, kernel set, crop water use, corn

Introduction

Definition of Macromanagement and Scope of the Problem

Corn (Zea mays L.) is the primary irrigated crop in the U.S. Great Plains. There are a number of efficient methods to schedule irrigation for corn on a real-time, daily, or short-term basis throughout the season. These scheduling methods essentially achieve water conservation by delaying any unnecessary irrigation event with the prospect that the irrigation season might end before the next irrigation event is required. There are larger irrigation management decisions [i.e., irrigation macromanagement (Lamm et al., 1996)] that can be considered separately from the step-by-step, periodic scheduling procedures. Two important macromanagement decisions occur at the seasonal boundaries, the initiation and termination of the irrigation season. Irrigators sometimes make these seasonal boundary determinations based on a traditional time-of-year rather than with sound rationale or science-based procedures. However, a single, inappropriate, macromanagement decision can easily have a larger effect on total irrigation water use and/or crop production than the cumulative errors that might occur due to small, systematic errors in soil-, plant-, or climatic-based scheduling procedures. This does not discount step-by-step irrigation scheduling. To the contrary, it is an implicit assumption that improved macromanagement at the seasonal boundaries can only provide the potential for increased water conservation when used in conjunction with the step-by-step, periodic scheduling procedures. This paper will concentrate on the effect of water stresses during the period prior to corn anthesis (i.e., flowering or termed tasseling in corn).

Pre-Anthesis Water Stress

Most of the established literature on irrigation management during the early growth stages is 35-45 years old and was written at a time when irrigated corn yields were much lower (3 to 6.5 Mg/ha lower) than they are today. It is quite possible that some of the numerous yield-limiting stresses (e.g., water, insects, weeds, nutrient, and soil) that were tolerable at the lower yield level are less tolerable today. On the other side of the issue, there has been much improvement in corn hybrids during the period with incorporation of traits that allow water stress tolerance and/or water stress avoidance.

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. The vegetative stage begins at crop emergence and ends after tasseling, which immediately precedes the beginning of the reproductive period when the silks start to emerge. The potential number of ears/plant is established by the fifth leaf stage in corn. The potential number of kernels/ear is established during the period from about the ninth leaf stage until about one week before silking. Stresses during the 10 to 14 days after silking will reduce the potential kernels/ear to the final or actual number of kernels/ear. Therefore, in research studies designed to examine water stresses during the first one-half of the corn crop season, both ears/plant and kernels/ear might be critical factors. Additionally, there could be permanent damaging effects from the vegetative and early-reproductive period water stress that may affect grain filling (kernel weight). Often, irrigators in the Great Plains, start their corn irrigation season after early season cultural practices are completed such as herbicide or fertilizer application or crop cultivation at the lay-by growth stage (approximately 0.45 to 0.60 m corn height). Crop evapotranspiration is increasing rapidly and drier weather periods are approaching, so often there is soil water storage that can be replenished by timely irrigation then for use later in the summer. However, this does not always mean that the corn crop required the irrigation at that point-in-time.

PROCEDURES

General Procedures

Two studies were conducted at the KSU Northwest Research-Extension Center at Colby, Kansas, USA on a productive, deep, well-drained Keith silt loam soil (Aridic Argiustolls) during the sixteen-year period, 1993-2008. In general, the 1990s were a much wetter period than the 2000s. The summers of 2000 through 2003 would be considered extreme droughts. The climate for the region is semi-arid with a summer pattern of precipitation with an annual average of approximately 480 mm. The average precipitation and calculated corn evapotranspiration during the 120-day corn growing period, May 15 through September 11 is 300 mm and 587 mm, respectively. The corn anthesis period typically occurs between July 15 and 20.

Both studies utilized the same field site that had a subsurface drip irrigation (SDI) system installed in 1990 with 1.5-m dripline spacing and an emitter spacing of 0.3 m. The 2.5-ft paced corn rows were planted parallel and centered on the driplines such that each corn row would be 15 inches from the nearest dripline. The nominal dripline flowrate was 0.25 gpm/100 ft, which is equivalent to an emitter discharge of 0.6 L/h for the 0.3 m emitter spacing.

The corn was planted in late April to early May, and standard cultural practices for the region were used.

Irrigation was scheduled as needed by a climate-based water budget except as modified by study protocols that will be discussed in the Specific Procedures section that follows. Calculated crop evapotranspiration (ETc) was determined with a modified Penman equation for calculating reference evapotranspiration (ETr) multiplied by empirical crop coefficients suitable for western Kansas. Precipitation and irrigation were deposits into the crop water budget and calculated ETc was the withdrawal.

Soil water was measured in each plot on a weekly or biweekly basis with a neutron probe to a depth of 2.4 m in 0.3-m increments. These data were used to determine crop water use and to determine critical soil water depletion levels. Water use values were calculated as the sum of the change in available soil water to the specified profile depth, plus the irrigation and precipitation during the specified period. This method of calculating crop water use would also include any deep percolation or rainfall runoff that may have occurred.

Corn yield and yield components of plants/area, ears/plant, and kernel weight were measured by hand harvesting a representative 6 m row sample. The number of kernels/ear was calculated with algebraic closure using the remaining yield components.

Specific Procedures for Pre-Anthesis Water Stress Studies

Data from two studies where the initiation date of the irrigation season was varied were combined in the analysis. The first study consisted of five years of data (1999 through 2003) with the hybrid Pioneer 3162 (full season, 118 days to maturity). The second study during the four-year period (2004 through 2007) used two corn hybrids [Pioneer 32B33 (full season, 118 days to maturity) and Pioneer 33B50 (medium season, 112 days to maturity)]. The 2004-2007 study had six main irrigation treatments and the two corn hybrid split-plot treatments replicated three times in a randomized complete block (RCB) design. The 1999-2003 study used the same experimental design without the split plot. The whole plots were 8 rows wide (6 m) and 600 m long.

The six irrigation treatments (pre-anthesis water stress studies) were imposed by delaying the first normal irrigation either 0, 1, 2, 3, 4, or 5 weeks. This typically resulted in the first irrigation for Trt 1 being between June 5 and June 15 and the first irrigation for Trt 6 being around July 10 to July 24. In some years, excessive rainfall between two adjacent treatment initiation dates would negate the need for irrigation. In that case, the later treatments would be delayed an additional week to provide an extended data set. After the treatment initiation date occurred, SDI was scheduled to provide 10 mm/d until such time that the climate-based water budget fully eliminated calculated soil water deficits. It should be noted that this irrigation capacity of 10 mm/d is much greater than the typical irrigation capacity in this region. Additionally, the procedure of eliminating the severe irrigation deficits later in the season after the plants had been stunted may lead to excessive deep percolation. The purpose of the study was not to optimize irrigation use within the study but rather to determine what capability the corn crop had to tolerate early season water stress. Thus, the procedures were tailored to alleviate soil water deficits relatively quickly after the treatment initiation date.

Analysis of variance (AOV) of the yield and yield component data was performed for the 6 treatments for the 1999-2003 data set using a one-way AOV and using a split plot two-way AOV for the 2004-2007 data set.

RESULTS AND DISCUSSION

Statistical and tabular data analysis for pre-anthesis water stress studies

Delaying irrigation only statistically affected the yield components in three of the nine crop years and then only for the later irrigation dates (Tables 1 and 2). Delaying irrigation until July 10, 2001, July 17, 2003 and July 27, 2005 significantly reduced the number of kernels/ear and the grain yield. These three years had an average weather-based calculated July crop ET_c rate of 8.1 mm/d. In comparison the average July crop ET_c rate value was 6.6 mm/d for the other six years. It should be noted that the years 2000 through 2003 were extreme drought years in northwest Kansas. Delaying irrigation also significantly reduced ears/plant in 2003 and 2005. In 2003, the reduction in kernels/ear and ears/plant for Trt 6 was partially compensated for by a statistically higher kernel weight. Overall, these results suggest that corn grown on this soil type has great ability to handle vegetative and early-reproductive period water stress provided the water stress can be alleviated during the later stages.

The hybrid selection affected yield in only one of the four years, 2006, with the longer season Pioneer 32B33 providing significantly greater yields for the later irrigation initiation dates (Table 2). This is probably because of earlier pollination for the Pioneer 33B50 prior to receiving irrigation. Kernels/ear was significantly less for the shorter season Pioneer 33B50 hybrid in three of four years. Hybrid selection did not affect ears/plant in any of the four years. In 2004, kernel weight was significantly higher for Pioneer 33B50 for some irrigation treatments, probably because of the smaller number of kernels/ear for this hybrid in that year.

It should be noted that the results do not mean that irrigation can be delayed in the Western Great Plains until mid to late July. These plots generally started the season with reasonably full soil profiles. Most irrigators do not have irrigation systems with adequate capacity (gpm/acre) to quickly alleviate severely depleted soil water reserves. In addition, it is difficult to infiltrate large amounts of water into the soil quickly with sprinkler and surface irrigation systems without causing runoff problems. Rather, look at these study results as describing the corn plant's innate ability to tolerate vegetative-period water stress.

Table 1. Summary of yield component and irrigation data from an early season water stress study for corn hybrid Pioneer 3162, KSU-NWREC, Colby, Kansas, 1999-2003.

Year and Parameter		Trt 1	Trt 2	Trt 3	Trt 4	Trt 5	Trt 6
1999	First Irrigation Date	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul
	Total Irrigation (mm)	284	284	284	254	254	193
	Yield (Mg/ha)	15.9 a*	16.6 a	16.1 a	16.0 a	16.3 a	16.0 a
	Plant Pop. (p/ha)	76781 a	79650 a	78934 a	78215 a	79650 a	79650 a
	Ears/Plant	0.99 a	0.99 a	0.97 a	1.00 a	0.99 a	1.01 a
	Kernels/Ear	575 a	570 a	555 a	572 a	543 a	555 a
	Kernel Wt. (g/100)	36.3 a	36.9 a	37.8 a	35.8 a	38.1 a	35.9 a
2000	First Irrigation Date	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul
	Total Irrigation (mm)	500	500	500	480	480	480
	Yield (Mg/ha)	14.1 a	14.8 a	14.1 a	14.2 a	13.6 a	13.6 a
	Plant Pop. (p/ha)	68887 a	69606 a	66018 a	66018 a	66734 a	67451 a
	Ears/Plant	1.02 a	1.04 a	0.99 a	1.03 a	1.02 a	1.01 a
	Kernels/Ear	544 a	553 a	568 a	544 a	548 a	529 a
	Kernel Wt. (g/100)	36.9 a	36.8 a	38.0 a	38.4 a	36.4 a	37.8 a
2001	First Irrigation Date	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul
	Total Irrigation (mm)	488	488	488	488	488	488
	Yield (Mg/ha)	15.9 a	16.3 a	16.4 a	15.7 a	13.4 b	10.0 c
	Plant Pop. (p/ha)	83957 a	86468 a	86286 a	87187 a	85035 a	83596 a
	Ears/Plant	0.96 a	0.98 a	0.99 a	0.99 a	0.97 a	0.99 a
	Kernels/Ear	581 a	584 a	582 a	541 a	476 b	347 c
	Kernel Wt. (g/100)	33.8 a	33.2 a	32.8 a	33.7 a	34.6 a	34.9 a
2002	First Irrigation Date	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul
	Total Irrigation (mm)	470	457	457	457	457	457
	Yield (Mg/ha)	14.6 a	14.6 a	13.6 a	13.7 a	13.9 a	14.0 a
	Plant Pop. (p/ha)	85393 a	86109 a	85393 a	88262 a	88262 a	85393 a
	Ears/Plant	0.98 a	0.97 a	0.98 a	0.99 a	1.00 a	0.99 a
	Kernels/Ear	454 a	443 a	407 a	435 a	391 a	422 a
	Kernel Wt. (g/100)	38.6 a	39.8 a	40.3 a	36.6 a	40.5 a	39.2 a
2003	First Irrigation Date	12-Jun	21-Jun	26-Jun	3-Jul	10-Jul	17-Jul
	Total Irrigation (mm)	478	457	457	437	437	5.8
	Yield (Mg/ha)	11.1 a	11.3 a	11.9 a	11.7 a	10.7 a	93 b
	Plant Pop. (p/ha)	81086 a	82522 a	84674 a	81805 a	85393 a	81086 a
	Ears/Plant	0.96 a	0.92 b	0.96 a	1.00 a	0.97 a	0.82 c
	Kernels/Ear	588 a	567 a	576 a	569 a	486 b	262 c
	Kernel Wt. (g/100)	24.1 b	26.2 b	25.5 b	25.2 b	26.8 b	33.6 a

** Values followed by the same lower case letters are not significantly different at P=0.05.*

Table 2. Summary of corn yield component and irrigation data from an early season water stress study for hybrids Pioneer 33B50 and 32B33, KSU-NWREC, Colby, Kansas, 2004-2007.

Year and Parameter	**Hybrid**	**Trt 1**	**Trt 2**	**Trt 3**	**Trt 4**	**Trt 5**	**Trt 6**
2004 First Irrigation		8-Jun	28-Jun	13-Jul	20-Jul	27-Jul	3-Aug
Total Irrig. (mm		325	295	274	274	274	274
Yield (Mg/ha)	33B50	13.8 aA*	13.4 aA	12.9 aA	14.6 aA	15.4 aA	13.2 aA
	32B33	14.2 aA	13.2 aA	13.1 aA	13.9 aA	14.4 aA	12.9 aA
Plant Pop. (p/ha)	33B50	71758 aA	69606 aA	69606 aA	69606 aA	71041 aA	68887 aA
	32B33	70322 aA	73193 aA	73193 aA	70322 aA	71758 aA	70322 aA
Ears/Plant	33B50	0.85 aA	0.91 aA	0.89 aA	0.93 aA	0.88 aA	0.84 aA
	32B33	0.88 aA	0.80 aA	0.79 aA	0.90 aA	0.83 aA	0.83 aA
Kernels/Ear	33B50	595 aB	574 aB	589 aB	595 aA	648 aA	590 aB
	32B33	624 aA	616 aA	634 aA	600 aA	643 aA	612 aA
Kernel Wt. (g/100)	33B50	38.0 aA	36.8 aA	35.7 aA	38.2 aA	38.2 aA	38.6 aA
	32B33	36.8 aB	36.4 aA	36.2 aA	36.8 aB	37.6 aA	36.4 aB
2005 First Irrigation	**Hybrid**	21-Jun	28-Jun	6-Jul	12-Jul	19-Jul	26-Jul
Total Irrig. (mm)		335	335	335	335	335	335
Yield (Mg/ha)	33B50	14.2 aA	16.3 aA	16.1 aA	14.9 abA	14.2 bA	9.4 cA
	32B33	14.2 abc	14.2 ab	16.2 abA	16.6 aA	14.8 cA	10.2 dA
Plant Pop. (p/ha)	33B50	71041 aA	70322 aA	70322 aA	70322 aA	73193 aA	69606 aA
	32B33	70322 aA	71758 aA	70322 aA	68812 aA	71041 aA	73193 aA
Ears/Plant	33B50	0.99 ab	1.00 aA	0.99 abA	0.98 abA	0.96 bcA	0.95 cA
	32B33	0.98 bA	0.97 bc	1.01 aA	1.00 abA	0.96 bcd	0.94 dA
Kernels/Ear	33B50	641 ab	653 aA	670 aA	604 bA	564 cA	422 dA
	32B33	638 bA	647 ab	644 abA	680 aA	654 abA	421 cA
Kernel Wt. (g/100)	33B50	35.4 aA	35.4 aA	34.5 aA	36.0 aA	35.9 aA	33.6 aA
	32B33	36.2 aA	35.4 aA	35.4 aA	35.5 aA	33.1 aA	35.1 aA
2006 First Irrigation	**Hybrid**	8-Jun	15-Jun	26-Jun	29-Jun	6-Jul	14-Jul
Total Irrig. (mm)		356	345	325	325	315	315
Yield (Mg/ha)	33B50	14.1 aA	14.4 aA	13.8 aB	13.8 aA	13.8 aB	12.9 aB
	32B33	14.4 aA	14.7 aA	15.4 aA	14.4 aA	15.1 aA	15.3 aA
Plant Pop. (p/ha)	33B50	68170 aA	66734 aA	69606 aA	69606 aA	68170 aA	67451 aA
	32B33	70322 aA	68887 aA	70322 aA	68887 aA	69603 aA	69606 aA
Ears/Plant	33B50	0.98 aA	0.98 aA	0.99 aA	0.99 aA	0.99 aA	0.96 aA
	32B33	0.96 aA	0.98 aA	0.98 aA	0.97 aA	0.98 aA	0.97 aA
Kernels/Ear	33B50	561 aB	594 aA	544 aB	547 aB	550 aB	519 aB
	32B33	597 aA	602 aA	618 aA	583 aA	585 aA	612 aA
Kernel Wt. (g/100)	33B50	37.8 aA	37.2 aA	36.8 aA	36.5 aA	37.4 aA	38.7 aA
	32B33	35.7 aA	36.2 aA	36.3 aA	37.1 aA	38.1 aA	37.2 aA
2007 First Irrigation	**Hybrid**	7-Jun	21-Jun	28-Jun	4-Jul	12-Jul	19-Jul
Total Irrig. (mm)		307	287	287	287	287	277
Yield (Mg/ha)	33B50	15.3 aA	15.8 aA	15.7 aA	15.4 aA	14.7 aA	13.4 aA
	32B33	16.3 aA	14.8 aA	15.8 aA	15.0 aA	16.0 aA	14.4 aA
Plant Pop. (p/ha)	33B50	71758 aA	73193 aA	72477 aA	70322 aA	71758 aA	69606 aA
	32B33	71758 aA	70322 aA	69606 aA	68887 aA	70322 aA	69606 aA
Ears/Plant	33B50	0.98 aA	0.99 aA	1.00 aA	0.99 aA	0.99 aA	1.00 aA
	32B33	0.98 aA	0.95 aA	0.99 aA	0.99 aA	0.99 aA	0.97 aA
Kernels/Ear	33B50	668 aB	672 aB	693 aA	682 aA	645 aB	597 aB
	32B33	728 aA	724 aA	712 aA	712 aA	714 aA	674 aA
Kernel Wt. (g/100)	33B50	32.5 aA	32.5 aA	31.2 aA	32.4 aA	32.0 aA	32.2 aA
	32B33	31.6 aA	30.6 aA	32.3 aA	30.9 aA	32.3 aA	31.7 aA

* *Irrigation treatment values within the same row followed by the same lower case letters are not significantly different at P=0.05, and hybrid treatment values within the same column followed by the same upper case letters are not significantly different at P=0.05.*

Graphical data analysis for pre-anthesis water stress studies

The tabular data do not give a mechanistic explanation of the results. Attempts were made to relate yield component data to a large number of water factors in the broad categories of water use, evaporative demand, and critical profile soil water levels. Relative values of yield and yield components were determined by normalizing each data point to the corresponding value for the earliest irrigation treatment in that year. These relative values were used for comparisons between years. Final grain yield was largely determined by the number of sinks or kernels/area (plants/area x ears/plant x kernels/ear) indicating there was little or no effect on the grain-filling stage imposed by the vegetative and early-reproductive period water stress in these two studies (Figure 1). The individual treatment values of corn grain yield and kernels/area were values compared to the irrigation treatment that had no initial delay in irrigation (Trt 1) to give relative values. In a few cases, the Trt 1 values were not the highest value and, thus, relative values could be greater than one. Deviations below the 1 to 1 unity line in Figure 1 would indicate a permanent negative effect on corn grain yield of early-season water stress because of reduced kernels/area. Deviations above the line would indicate some grain yield compensation resulting from better grain filling of the reduced kernels/area.

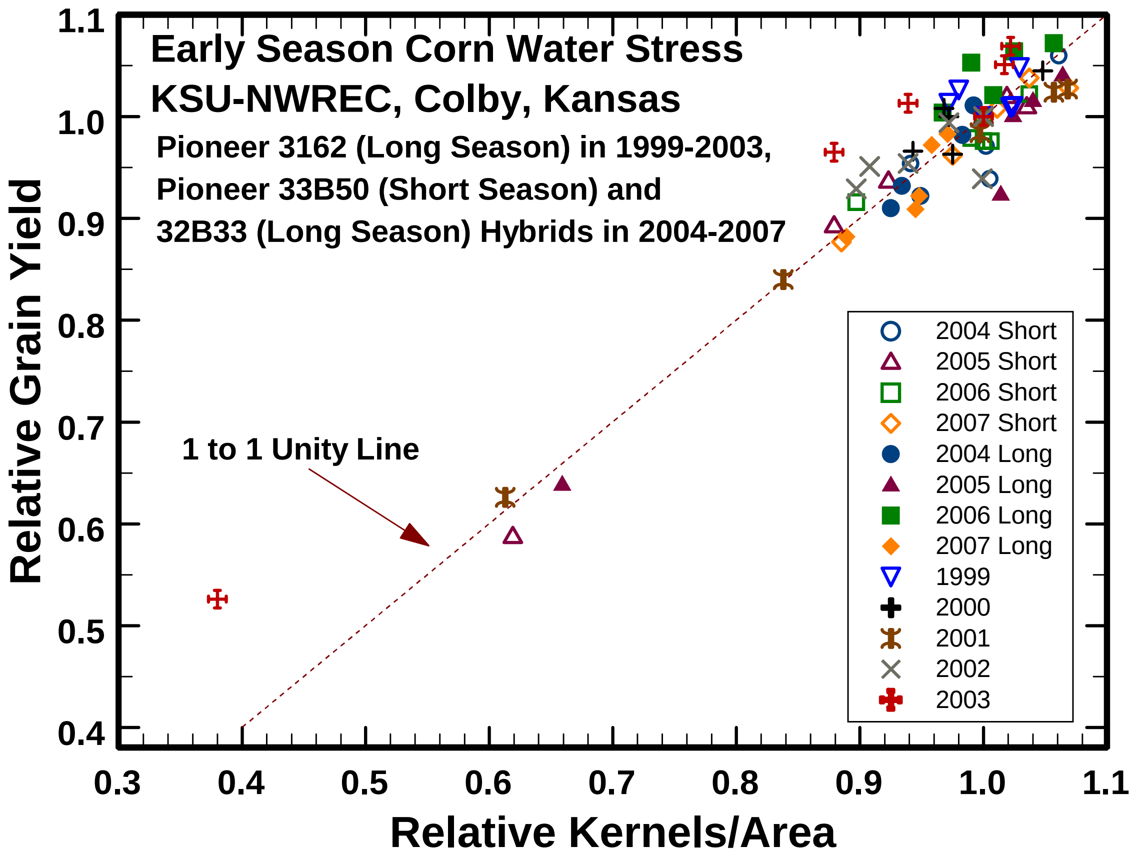

Figure 1. Relative corn grain yield as affected by relative kernels/area in an early-season corn water stress study, KSU-NWREC, Colby, Kansas, 1999-2007.

Relative kernels/area was found to be reasonably well related to relative July water use, the minimum available soil water in the top 1.2 mt of the soil profile during July and to the July 1 through July 15 water deficit (Ratio of calculated well-watered corn ETc to the sum of irrigation and precipitation). Further analysis is needed to determine an improved overall relationship involving more than a single factor, but the individual factor results will be discussed here.

The 50% critical silking period for corn in this study ranged from approximately July 17 to July 22 during the study period (1999 to 2007). The short-season hybrid in the latter study would typically silk approximately one week earlier. A window of approximately two weeks on both sides around the silking period was used to compare the relative kernels/area to the relative July measured water use (sum of change in available soil water in July plus July irrigation and precipitation). Actual soil water measurements were taken on an approximately weekly basis except for equipment problems or when excessive precipitation delayed measurements, so it was not possible with the data set to always have exactly 31 days of water use. Dates used were those closest to July 1 through 31. There tended to be some reduction in relative kernels/area when relative July water use was less than 80% (Figure 2). Scatter at the lower end of relative July water use may be related to water-use differences occurring within the month or differences in evaporative demand between the years. This relationship may not result in a very good signal for procedures to determine irrigation need because the relative July water use cannot be determined until it is too late to handle the reduction in relative kernels/area.

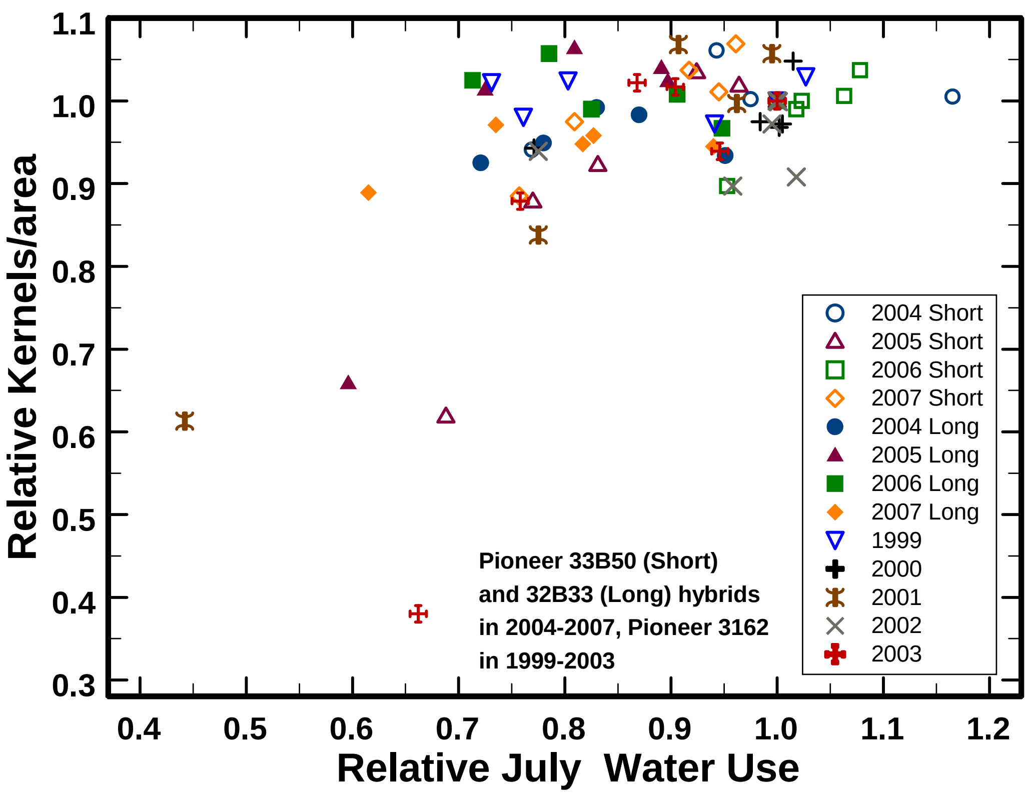

Figure 2. Relative corn grain yield as affected by relative July water use in an early-season corn water stress study, KSU-NWREC, Colby, Kansas, 1999-2007.

The relative kernels/area tended to be reduced when July minimum available soil water in the top 1.2 m (JASW) was below 0.6 (fraction) in some years (Figure 3). During years of less evaporative demand, water could be extracted from the soil profile to a further reduced level without much detriment to relative kernels/area, but severe reductions occurred for similar soil water conditions in years with large July evaporative demands. The upper and lower envelope lines of Figure 3 were manually drawn to indicate the effect of evaporative demand of the given year on relative kernels/area. These envelopes would match known theories of water stress and water flow through plants (Denmead and Shaw, 1962).

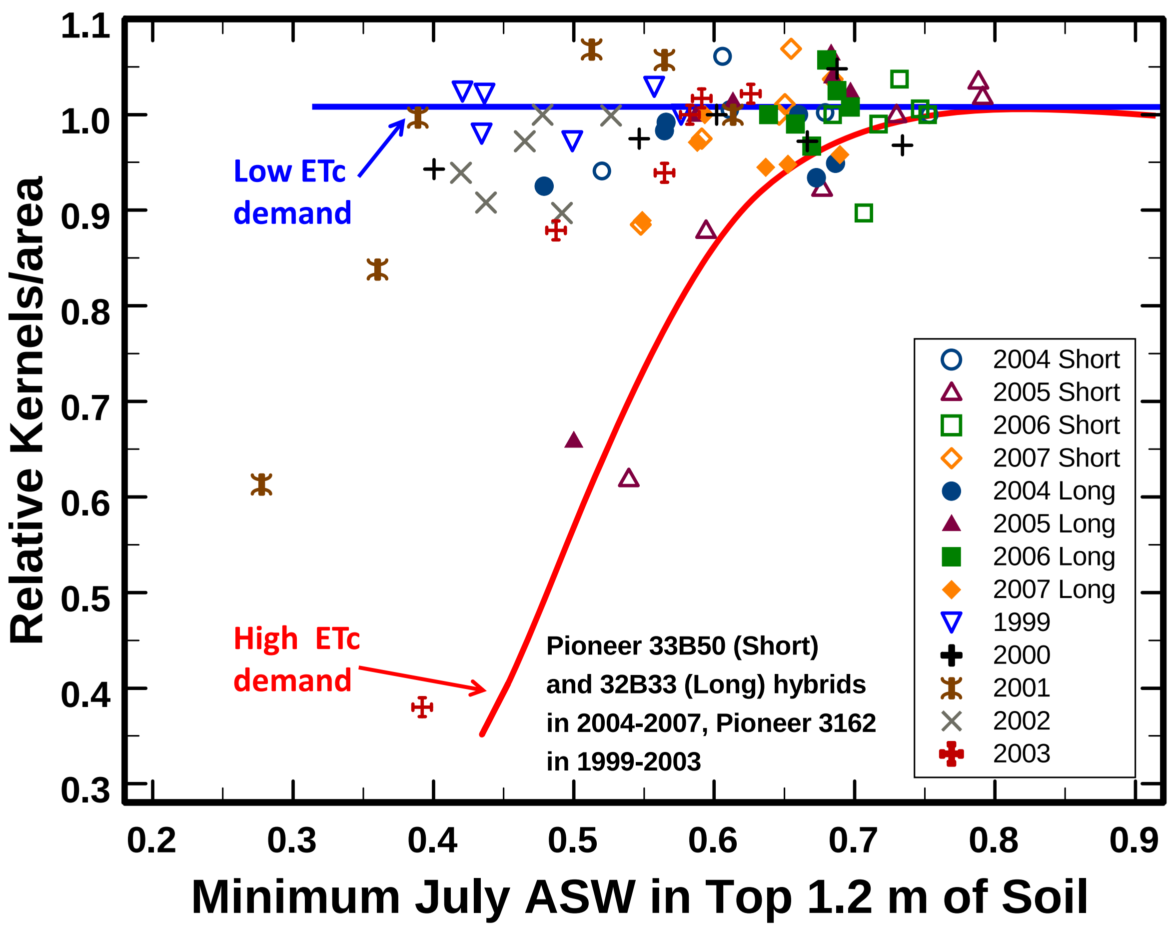

Figure 3. Relative kernels/area as affected by July minimum available soil water in the top 1.2 m of soil in an early-season corn water stress study, KSU-NWREC, Colby, Kansas, 1999-2007. The upper (red) and lower (blue) lines are manually drawn to illustrate years with larger and smaller July evaporative demand.

Water stress is greater both with reduced available soil water and with greater evaporative demand. The kernels/area was most sensitive to the JASW in the top 4 ft of soil as compared to both smaller and greater profile depths. This is reflecting the approximate rooting and soil water extraction depth of corn in July on this soil type. There remains considerable unexplained scatter in this graph that does not appear to be related very well to differences in evaporative demand between the years. For example, there was very little effect on relative kernels/area in 2002, although it had a moderately high evaporative demand. The relationship of relative kernels/area to a critical level of available soil water can have some merit as a signal for determining the need for irrigation because available soil water can both be measured in real-time and the value can be projected a few days into the future.

The ratio of calculated well-watered crop ET_c to the sum of irrigation and precipitation for July 1 through 15 was also related to the relative kernels/area (Figure 4). The relative kernels/area tended to decrease when this water deficit ratio was less than 70 to 80%. Attempts were also made in varying the timeframe of the ratio (both longer and shorter and also shifting within the month of July). It appears that some of the remaining scatter in this graph is related to timing of irrigation and precipitation near the actual point of silking. For example, the isolated point from 2002 near the vertical axis may be related to a significant precipitation event that occurred near silking, but later than July 15. Further analysis should be conducted to allow the window to actually vary around the individual silking dates of each year. This might be done by computing windows based on the number of thermal units (also known as Growing Degree Days) required for silking. This relationship might also be a good signal in determining the need for irrigation because it can be determined in near real-time using the accumulated ratio to that point in time.

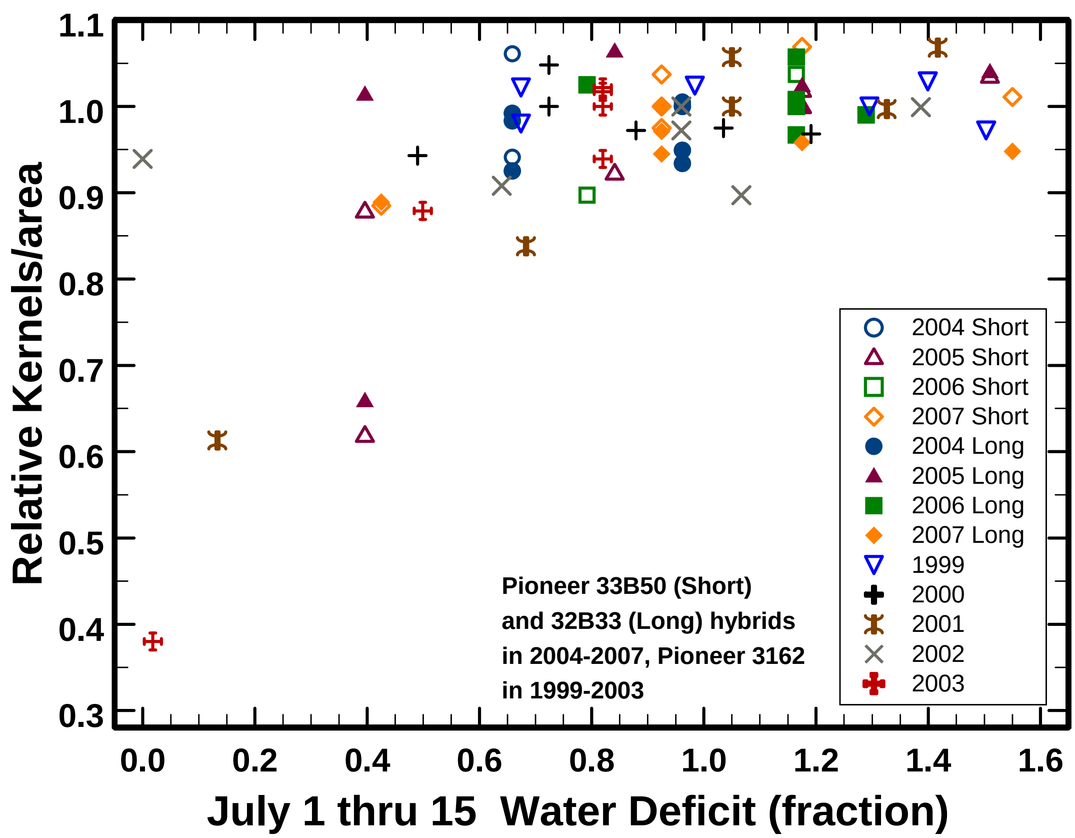

Figure 4. Relative kernels/area as affected by the July 1 through 15 water deficit (ratio of calculated well-watered crop ET_c to the sum of irrigation and precipitation) in an early-season corn water stress study, KSU-NWREC, Colby, Kansas, 1999-2007.

Further analysis should focus on attempts to combine multiple factors (e. g., measured water use, available soil water, evaporative demand, and/or timing of irrigation and precipitation) with a focus on developing irrigation signals that can be used in near real-time to make early season irrigation decisions.

Recommendations for managing pre-anthesis corn water stress

Producers should use a good method of day-to-day irrigation scheduling during the pre-anthesis period. To a large extent the information being used to make day-to-day irrigation scheduling decisions during the pre-anthesis period can also be used as in making the macromanagement decision about when to start the irrigation season. This is because even though the corn has considerable innate ability to tolerate early season water stress, most irrigation systems in the Central Great Plains do not have the capacity (e.g, L/s) or practical capability (e.g., run-off or deep percolation concerns) to replenish severely depleted soil water reserves as the season progresses to periods of greater irrigation needs (i.e., greater ET_c and less precipitation). However, there is some flexibility in timing of irrigation events within the vegetative growth period. In years of lower evaporative demand, corn grown on this soil type in this region can extract greater amounts of soil water without detriment. Timeliness of irrigation and/or precipitation near anthesis appears to be important in establishing an adequate number of kernels/area. The strong linear 1:1 relationship that existed between the relative corn yield and the relative number of kernels/area (plants/area x ears/plant x kernels/ear) indicates that optimizing kernels/area is a key in optimizing grain yields. Producers growing corn on deep silt loam soils in the Central Great Plains should attempt to maintain a water deficit ratio (well watered calculated ETc divided by sum of irrigation and precipitation) during July of approximately 0.7 to 0.8 and not allow the available soil water within a 1.2 m soil profile to decrease below 70%, particularly in years of greater evaporative demand.

CONCLUDING STATEMENTS

Macromanagement decisions at the seasonal boundaries should always be made in the context of having implemented appropriate day-to-day irrigation scheduling. Proper day-to-day scheduling will provide much-needed information about the crop and soil water status and evaporative demand being experienced within the given year.

Corn has greater than anticipated ability to withstand early season water stress provided that the water stress can be alleviated during the early-reproductive period. However, it should be reiterated that these results are not suggesting that irrigation can be delayed until anthesis. Most irrigation systems cannot quickly alleviate severely depleted soil water reserves as was accomplished in this pre-anthesis studies, but the results do indicate there is some flexibility in timing of irrigation events within the vegetative growth period. Timeliness of appreciable amounts of irrigation and/or precipitation near anthesis appears to be very important in maximizing yield potential.

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