Timing of the First Irrigation in Corn and Moisture Stress Conditioning

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Abstract

Delaying the first irrigation is thought to encourage root growth and condition crops for stress later in the season. Our objective was to test this common practice using corn. Field studies were conducted in Tucson, Arizona in 1989 and 1990 in which the first irrigation was applied at the 2, 4, or 8-leaf stages, and then either irrigated or stressed at anthesis. Delaying the first irrigation either restricted or did not influence root growth. Water use during anthesis was increased if the first irrigation was delayed, especially at the 2 to 3-foot depth. Delaying the first irrigation delayed silking by approximately 3 days and decreased the rate of dry matter accumulation. Grain yield was decreased 20% and total plant yield was decreased 14% in 1990 where the first irrigation was delayed past the 2-leaf stage and the crop was well-watered at anthesis. Timing of the first irrigation did not affect yield if irrigations were withheld at anthesis. Delaying the first irrigation does not appear to condition corn for moisture stress later in the season, and may substantially decrease yield in certain situations.

Introduction

A common notion among farmers is that early season moisture stress encourages root growth and conditions the crop for stress later in the season. In irrigated areas, delaying the first irrigation is thought to benefit crops such as alfalfa, barley, corn and cotton.

Crops enduring mild stress or growing in soils with limited water availability tend to have a deeper rooting pattern than well-watered controls (Malik et al., 1979; Sharp and Davies, 1985). The degree of stress or the soil moisture content necessary to encourage root growth is not well documented.

The phenomenon of water stress conditioning is well known for plants grown in greenhouses for transplanting purposes (Clemens and Jones, 1978; Seiler and Johnson, 1988). Various physiological mechanisms have been identified as responsible for water stress conditioning such as increased stomatal control, enhanced root hydraulic conductivity, and maintenance of photosynthesis at higher levels of water stress (Boyer and McPherson, 1975; Cutler and Rains, 1987; Clemens and Jones, 1978). Field-grown plants are subjected to greater changes in water use than greenhouse grown plants due to a less constant environment. Water stress conditioning of field grown plants has been reported but usually only in the case of severe stress after the conditioning period (Stewart et al., 1975; Garrity et al., 1983).

Our objective was to test the hypothesis that delaying the first irrigation encourages root growth and conditions the plant for water stress later in the season.

Materials and Methods

Field studies were conducted at the Campus Agricultural Center in Tucson in 1989 and 1990 on an Aqua sandy clay loam. Nitrogen was applied preplant in 1990 only at a rate of 63 lbs N/acre as ammonium nitrate. Atrazine was applied preplant for weed control in 1989 and Thimet was applied preplant for root worm control in 1990. The field was pre-irrigated and Pioneer Brand corn hybrid 3183 was planted in 40-inch rows on 22 March 1989 and 3 April 1990. Approximately 50% more seed was planted than desired as a final stand, and the plants were thinned to one plant per 6 inches in the row at the 2-leaf stage. Nitrogen was applied post-emergence as UAN 32 (32-0-0) at the 8 and 16-leaf stage at a rate of 75 lbs. N/acre in 1989 and at the 8-leaf stage at a rate of 100 lbs N/acre in 1990. Diazinon was applied as granules in the whorls of the plant to control southwestern corn borer and the corn ear worm at the 8 and 13-leaf stage in 1989 and the 4 and 8-leaf stage in 1990.

The first irrigation was applied at 2, 4, or 8-leaf stage. During anthesis, the plots were either irrigated daily or not irrigated until 80% of the plant available water was depleted. Thus, the total number of treatments was six: three timings of the first irrigation times two irrigation regimes at anthesis. The experimental design was a randomized complete block with five replications. Plot size was 13.3 feet by 40 feet.

Water was applied using drip hoses when approximately 50% of the plant available water was depleted, except for the early irrigations and irrigations at anthesis. Water was measured with meters in line with each of the four laterals servicing seven to eight plots each. Soil moisture depletion to a 5-foot depth was measured before and after irrigations using a neutron probe. Crown root number was counted for 10 plants sampled at the 4 and 8-leaf stages. At anthesis, soil was sampled to a depth of 4 feet, roots were separated from soil, and root length was determined with an image analyzer. Total plant yield was determined from oven dry weights of 10 plants sampled at the 4-leaf, 8-leaf, 16-leaf, and milk stages and from a 5-foot length of row at harvest. Transpiration and stomatal conductance was measured using a porometer and canopy light interception using a sunfleck ceptometer at the dough stage in 1990. Grain was harvested from the two center rows of the four-row plots from a length of 20 feet in 1989 and 15 feet in 1990. The harvested grain was analyzed for yield components including weight per kernel, kernels per ear, and ears per unit area. Grain yield was adjusted for moisture content.

Results and Discussion

Delaying the first irrigation decreased the number of roots initiated at the crown as measured at the 4 and 8-leaf stages (data not presented). At anthesis, differences in root length as a result of the timing of the first irrigation were generally negligible (Table 1). The exception was the 3 to 4-foot depth in 1989 where root length was substantially increased as a result of applying the first irrigation early at the 2-leaf stage.

Water use from the 2-leaf stage to anthesis was decreased as the first irrigation was delayed (Table 2). This trend was maintained by depth increments in the soil except at the 3 to 5-foot level in the case of the first irrigation applied at the 4-leaf and 8-leaf stages. Water use during anthesis for treatments not irrigated during this time period was not affected by timing of the first irrigation in 1990. In 1989, however, a delay in the initial irrigation resulted in increased total water use during anthesis especially at the 2 to 3-foot depth.

Radiation interception, stomatal resistance, and transpiration were not affected by irrigation treatment measured at the dough stage in 1990 (Table 3). A delay in the first irrigation delayed anthesis by 3 to 4 days, as indicated by silking, and delayed physiological maturity by 1 to 2 days, as indicated by grain moisture content.

A delay in the first irrigation decreased plant dry weight at all growth stages sampled up to the milk stage (Table 4). The irrigation regime at anthesis had a pronounced effect on yield (Table 4). Delaying the first irrigation decreased grain and total plant yield in 1990, but not in 1989. Delaying the first irrigation decreased harvest index where irrigation was withheld at anthesis. The yield component decreased the most by delaying the first irrigation was kernels per ear.

Delaying the first irrigation does not appear to benefit the corn plant according to the results of our study. Under well-watered conditions, delaying the first irrigation may actually decrease yield. The yield decrease with a delay in irrigation may be due to growth occurring in more unfavorable weather due to a delay in anthesis, decreased yield potential due fewer kernels initiated at the ear shoot initiation stage (i.e., approximately 5-leaf stage), or possibly due to a decreased carbohydrate status of the plant hindering kernel formation during anthesis.

Comparing the results of this study to others reported in the scientific literature is difficult due to differing conditions and irrigation treatments. The water stress conditioning response reported by Stewart et al. (1975) and Garrity et al. (1983) may have resulted from the long duration of the conditioning period (emergence to anthesis) or the severity of the stress (yield of stressed 10 times less than well-watered). Conditioning responses were not detected in experiments conducted somewhat similar to ours in North Dakota (Stegman, 1982) and in Missouri (Miller and Duley, 1925). Water stress conditioning appears to depend on the degree and timing of the stress. Our results indicate that the type of stress endured by delaying the first irrigation under our growing regime does not result in water stress conditioning and may actually decrease yield.

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Table 1. Root density by depth near anthesis as affected by timing at the first irrigation.

Year	First Irrigation	Root Density Depth (ft) 0 - 1	1 - 2	2 - 3	3 - 4	Sum
		cm/cm^3 soil				
1989	2-leaf	1.96	0.74	0.74	0.85	4.29
	4-leaf	1.88	0.68	0.82	0.39	3.77
	8-leaf	1.90	0.86	0.64	0.35	3.74
	* LSD (10%)	NS	0.106	0.143	0.208	0.393
1990	2-leaf	2.58	0.72	0.28	0.16	3.74
	4-leaf	2.69	0.65	0.26	0.10	3.70
	8-leaf	2.49	0.74	0.25	0.12	3.60
	LSD (10%)	NS	NS	NS	NS	NS

* LSD (10%) = least significant differences at the 10% probability level.
NS = not significant at the 10% probability level.

Table 2a. Water use by depth summed over certain time periods between emergence and anthesis as affected by timing of the first irrigation.

Year	First Irrigation	Water Use Depth (ft) 0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	Sum
		inches					
1989	2-leaf	2.74	1.24	1.30	0.50	0.09	5.87
	4-leaf	2.35	1.04	1.11	0.33	0.06	4.89
	8-leaf	2.00	0.90	0.46	0.28	0.15	3.79
	* LSD (10%)	0.26	0.20	0.23	0.16	0.09	0.77
1990	2-leaf	3.61	2.78	2.09	1.19	0.36	10.03
	4-leaf	2.88	2.39	2.01	0.54	0.14	7.96
	8-leaf	2.35	2.23	1.49	0.80	0.22	7.09
	LSD (10%)	0.30	0.33	0.39	0.31	0.16	0.75

* LSD (10%) = least significant difference at the 10% probability level.

Table 2b. Water use by depth for during anthesis for 7 days in 1989 and 9 days in 1990 as affected by timing of the first irrigation.

Year	First Irrigation	Water Use Depth (ft) 0-1	1-2	2-3	3-4	4-5	Sum
		inches					
1989	2-leaf	0.76	0.97	1.12	0.49	0.39	3.74
	4-leaf	0.70	0.72	0.92	0.55	0.45	3.34
	8-leaf	0.62	0.89	1.51	0.58	0.40	4.01
	LSD (10%)	0.11	0.16	0.43	NS	NS	0.35
1990	2-leaf	1.00	1.14	1.25	0.65	0.06	4.11
	4-leaf	0.93	1.09	1.10	0.63	0.10	3.85
	8-leaf	0.78	1.02	1.56	0.74	0.22	4.32
	LSD (10%)	0.17	NS	NS	NS	0.10	NS

* LSD (10%) = least significant difference at the 10% probability level.
NS = not significant at the 10% probability level.

Table 3. Various physiological and developmental factors as affected by timing of the first irrigation in 1990.

Anthesis Irrigation	First Irrigation	Silking	Light Interception	Stomatal Resistance	Transpiration	Grain moisture
		%	%	s/m	$g/m^2/s$	%
Yes	2-leaf	68	89	71	0.295	28.9
	4-leaf	36	87	76	0.291	31.4
	8-leaf	22	90	70	0.298	31.4
No	2-leaf	65	89	72	0.301	29.5
	4-leaf	36	87	70	0.316	30.3
	8-leaf	20	88	70	0.303	32.8
	* LSD (10%)	11.0	NS	NS	NS	0.59

* LSD (10%) = least significant difference at the 10% probability level.
NS = not significant at the 10% probability level.

Table 4. Plant dry weight at various growth stages as affected by timing of the first irrigation.

Anthesis Irrigation	First Irrigation	Plant dry weight 1989 4-leaf	8-leaf	16-leaf	Milk	1990 4-leaf	8-leaf	16-leaf	Milk
		---g/plant---							
Yes	2-leaf	0.85	10.8	74	318	1.5	22	116	215
	4-leaf	0.50	5.0	55	303	1.0	17	97	207
	8-leaf	-	1.4	42	277	-	12	83	178
No	2-leaf	-	-	-	278	-	-	-	185
	4-leaf	-	-	-	254	-	-	-	187
	8-leaf	-	-	-	243	-	-	-	168
	* LSD (10%)	0.23	2.0	3.2	26.6	0.27	1.5	10.1	14.8

* LSD (10%) = least significant difference at the 10% probability level.

Table 5. Yield and yield components as affected by timing of the first irrigation.

Anthesis Irrigation	First Irrigation	Yield** Grain	Stover	Cob	Total	Harvest Index	Kernel Weight	Kernels per ear	Ears per acre
		---Tons/acre---				%	mg		
					1989				
Yes	2-leaf	4.1	5.3	0.88	10.4	40	276	554	24,800
	4-leaf	4.0	5.2	0.83	10.1	40	275	536	24,800
	8-leaf	4.1	5.1	0.80	10.0	41	276	515	26,000
No	2-leaf	2.9	5.3	0.70	9.0	32	246	469	22,800
	4-leaf	2.5	5.4	0.65	8.5	29	256	376	23,500
	8-leaf	2.4	5.8	0.61	8.7	26	245	385	21,800
	* LSD (10%)	0.61	NS	0.113	1.18	4.5	16.2	60.7	2,370
					1990				
Yes	2-leaf	3.7	6.6	0.86	11.1	33	255	483	27,400
	4-leaf	3.0	6.0	0.78	9.8	31	252	440	25,200
	8-leaf	3.2	5.8	0.77	9.7	33	256	414	27,300
No	2-leaf	2.1	5.7	0.57	8.3	25	233	347	23,800
	4-leaf	1.9	5.7	0.69	8.3	22	242	278	24,900
	8-leaf	2.1	5.4	0.70	8.2	26	243	313	25,200
	LSD (10%)	0.43	0.87	0.072	1.06	4.6	14.1	65.5	3,160

*LSD (10%) = least significant difference at the 10% probability level.
NS = not significant at the 10% probability level.
** = yield expressed on a 0% moisture basis.