Weed Science, 54:928–933. 2006

Planting date influences critical period of weed control in sweet corn

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The critical period for weed control (CPWC) identifies the phase of the crop growth cycle when weed interference results in unacceptable yield losses; however, the effect of planting date on CPWC is not well understood. Field studies were conducted in 2004 and 2005 at Urbana, IL, to determine CPWC in sweet corn for early May (EARLY) and late-June (LATE) planting dates. A quantitative series of treatments of both increasing duration of interference and length of weed-free period were imposed within each planting-date main plot. The beginning and end of the CPWC, based on 5% loss of marketable ear mass, was determined by fitting logistic and Gompertz equations to the relative yield data representing increasing duration of weed interference and weed-free periods, respectively. Weed interference stressed the crop more quickly and to a greater extent in EARLY, relative to LATE. At a 5% yield-loss level, duration of weed interference for 160 and 662 growing-degree days (GDD) from crop emergence marked the beginning of the CPWC for EARLY and LATE, respectively. When maintained weed-free for 320 and 134 GDD, weeds emerging later caused yield losses of less than 5% for EARLY and LATE, respectively. Weed densities exceeded 85 plants m^{-2} for the duration of the experiments and predominant species included barnyardgrass, common lambsquarters, common purslane, redroot pigweed, and velvetleaf. Weed canopy height and total aboveground weed biomass were 300% and 500% higher, respectively, for EARLY compared with LATE. Interactions between planting date and CPWC indicate the need to consider planting date in the optimization of integrated weed management systems for sweet corn. In this study, weed management in mid-June–planted sweet corn could have been less intensive than early May–planted corn, reducing herbicide use and risk of herbicide carryover to sensitive rotation crops.

Nomenclature: Barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. ECHCG; common lambsquarters, *Chenopodium album* L. CHEAL; common purslane, *Portulaca oleracea* L. POROL; redroot pigweed, *Amaranthus retroflexus* L. AMARE; velvetleaf, *Abutilon theophrasti* Medicus ABUTH; sweet corn, *Zea mays* L. 'GH0937'.

Key words: Competition, critical weed-free period, integrated weed management, yield loss.

Determining the appropriate timing of weed control tactics is valuable in developing integrated weed managements systems (Knezevic et al. 2002; Rajcan and Swanton 2001) and has been the subject of extensive research in agronomic crops (Zimdahl 2004). A common approach in such research is to quantify the CPWC; a phase of the crop growth cycle when weed interference results in unacceptable yield losses. The CPWC is determined by characterizing functional relationships between two separately measured competition components: crop yield as a function of the duration of weed interference to identify the beginning of CPWC, and crop yield as a function of the duration of the weed-free period to identify the end of CPWC. In theory, weed competition before or after the CPWC will not reduce crop yield below acceptable levels.

CPWC approaches crop–weed competition from an applied aspect because results have the potential for direct application to crop production, especially in cropping systems with a reliance on POST herbicides (Knezevic et al. 2002). However, the exact outcome of crop–weed competition is dependent on site-specific factors, including climate variation, weed species composition, and crop-specific production issues (Rajcan and Swanton 2001). For example, nitrogen application influences crop–weed interactions (Dyck and Liebman 1994; Vengris et al. 1955), including the critical period for weed control in dent corn (Evans et al. 2003). Planting date also influences crop losses due to weeds. Delayed planting reduced yield losses due to weeds in soybean [*Glycine max* (L.) Merr.] (Buhler and Gunsolus 1996) and dent corn (Gower et al. 2002), explained largely by low weed density resulting from depleted seed banks. Rushing and Oliver (1998) observed a trend for greater yield reduction from common cocklebur (*Xanthium strumarium* L.) interference in April-planted soybean than in May or July plantings. Despite the significance that planting date has on crop–weed competition, interactions between planting date and CPWC have not been reported.

Sweet corn, one of the most popular vegetable crops in North America, is planted over a wide range of dates to extend availability for fresh market and processing. In the north-central United States, sweet corn is planted commercially as early as the second week of April and as late as the first week of July. Although sweet corn is the same species as dent corn, sweet corn differs considerably in many genes that affect all phases of sweet corn growth (Azanza et al. 1996; Hassell et al. 2003; Treat and Tracy 1994) as well as crop production practices. Few reports of sweet corn–weed competition are available, although initial research indicates several ear traits associated with quality are significantly affected by weed interference (Williams and Masiunas, 2006). The objective of this study was to determine the critical period for weed control in sweet corn for early May and mid-June planting dates.

Materials and Methods

Site Description

Field experiments were conducted in 2004 and 2005 at the University of Illinois, Crop Sciences Research and Education Center, at Urbana, IL. The soil was a Flanagan silt loam (Fine, smectitic, mesic Aquic Argiudolls) with 3.6% organic matter and pH of 6.4. Experiments were located in different fields in each year. The previous crop was alfalfa (*Medicago sativa* L.) at the 2004 field and soybean at the 2005 field. Fields received 52 kg N ha^{-1}, 46 kg P ha^{-1}, and 54 kg K ha^{-1} on March 23, 2004, and 52 kg N ha^{-1}, 52 kg N ha^{-1}, and 67 kg N ha^{-1} on March 16, 2005.

Experimental Approach

The experimental design was a split plot with four replications. The main-plot factor was planting date, which consisted of seeding sweet corn the first week of May, hereafter referred to as "EARLY", and the third week of June, hereafter referred to as "LATE". The experimental area was chisel-plowed in the fall or spring, followed by one pass each of a disk harrow and a field cultivator before planting. Sweet corn was planted in 76-cm rows with a four-row vacuum planter.[1] Glufosinate-tolerant sweet corn ('GH0937', an 83-d *sugary1* endosperm mutant) was planted at 70,423 seeds ha^{-1} on May 6 (EARLY) and June 21 (LATE) in 2004 and May 2 (EARLY) and June 20 (LATE) in 2005.

A quantitative series of treatments of both increasing duration of interference and length of weed-free period were arranged as factorial designs within each planting-date main plot. Subplots measured 12.2 m in length by four rows wide (3.0 m). One set of treatments, increasing duration of interference, was established by delaying weed control from the time of crop planting until predetermined crop growth stages (weedy up to V2, V4, V6, V8, R1 [anthesis], and R3 [harvest]), at which time, weeds were removed, and plots were weeded throughout the rest of the season. The other set of treatments, increasing length of weed-free period, was established by maintaining weed control from the time of planting until the above-presented crop growth stages before allowing subsequent emerging weeds to remain for the rest of the season. In addition, season-long weedy and weed-free treatments were included. Growth stages were determined by the number of visible leaf collars and the appearance of reproductive organs (Ritchie et al. 2003).

Weed removal for establishing duration of interference and length of weed-free period treatments consisted of hand-hoeing, hand-weeding, and herbicide applications. A PRE application of 1.78 kg *S*-metolachlor ha^{-1} and 2.2 kg ha^{-1} atrazine was applied to season-long weed-free plots the day of crop planting. POST herbicides were applied using single- or multiple-nozzle handheld sprayers, calibrated to deliver a volume of 100 L ha^{-1} at a pressure of 207 kPa and 130 L ha^{-1} at a pressure of 276 kPa, respectively. The single-nozzle sprayer was used when crop canopy height exceeded 100 cm. For weed-removal events before R1, glufosinate was applied at a rate of 0.41 kg ai ha^{-1} with 5.0% (v/v) ammonium sulfate. For the R1 weed-removal event, weeds were cut to within 25 cm of the soil surface before herbicide application. Beginning 1 wk after the initial glufosinate application, all subsequent emerging weeds were removed by hoe or hand.

The experimental site was irrigated four times in 2005 (June 7, June 21, June 29, and August 9). Each irrigation event totaled 2.5 cm of water to offset abnormally low rainfall. Both years, permethrin was applied at 168 g ha^{-1} to control western corn rootworm (*Diabrotica virgifera* LeConte) beetles as needed.

Data Collection

Marketable ears were hand-picked 18 to 21 d after anthesis from the center two rows over 6.1 m of row. Harvest dates were August 2 (EARLY) and September 11 (LATE) in 2004 and July 27 (EARLY) and August 30 (LATE) in 2005. Ears were considered marketable if kernels were full, yellow, and had a moisture content of 75 $\pm$ 3%. Ears (including silks and husks) meeting these criteria exceeded 4.4 cm in diameter. Total mass of ears was recorded.

Within 2 d before each weed-removal event, weeds were sampled from within four 0.25-m^{-2} quadrats of each corresponding subplot. Quadrats were placed within 25 cm of center crop rows and 2.5 m from adjacent alleyways. Height of the primary weed canopy was measured, then weeds were clipped at the soil surface, sorted by species, counted, and weighed after oven-drying at 65 C.

GDD were determined using minimum and maximum air temperatures from a nearby weather station. A base temperature of 10 C was used as the minimum temperature for corn growth, and 30 C was used as the air temperature associated with optimal growth. The time of crop emergence was used as the reference point for accumulation of GDD.

Statistical Analyses

Relative yield of ear mass was calculated within each block as yield at a given weed-removal treatment divided by weed-free yield within that block. A three-parameter logistic equation (Knezevic et al. 2002) was used to describe the effect of increasing duration of weed interference on relative yield and to determine the beginning of the CPWC for each planting date:

$$y = [(1/\{\exp[kx(t - d)] + f\}) + [(f - 1)/f]] \times 100 \quad [1]$$

where y is relative yield of ear mass, t is the duration of weed interference after crop emergence (expressed in GDD), d is the point of inflection (expressed in GDD), and k and f are constants. The three-parameter Gompertz equation, modified slightly from the proposed form by Hall et al. (1992), was used to describe the effect of increasing duration of weed-free period on relative yield and to determine the end of the CPWC for each planting date:

$$y = a \times \exp\{-\exp[-(t - k)/b]\} \quad [2]$$

where y is relative yield of ear mass, a is the yield asymptote,

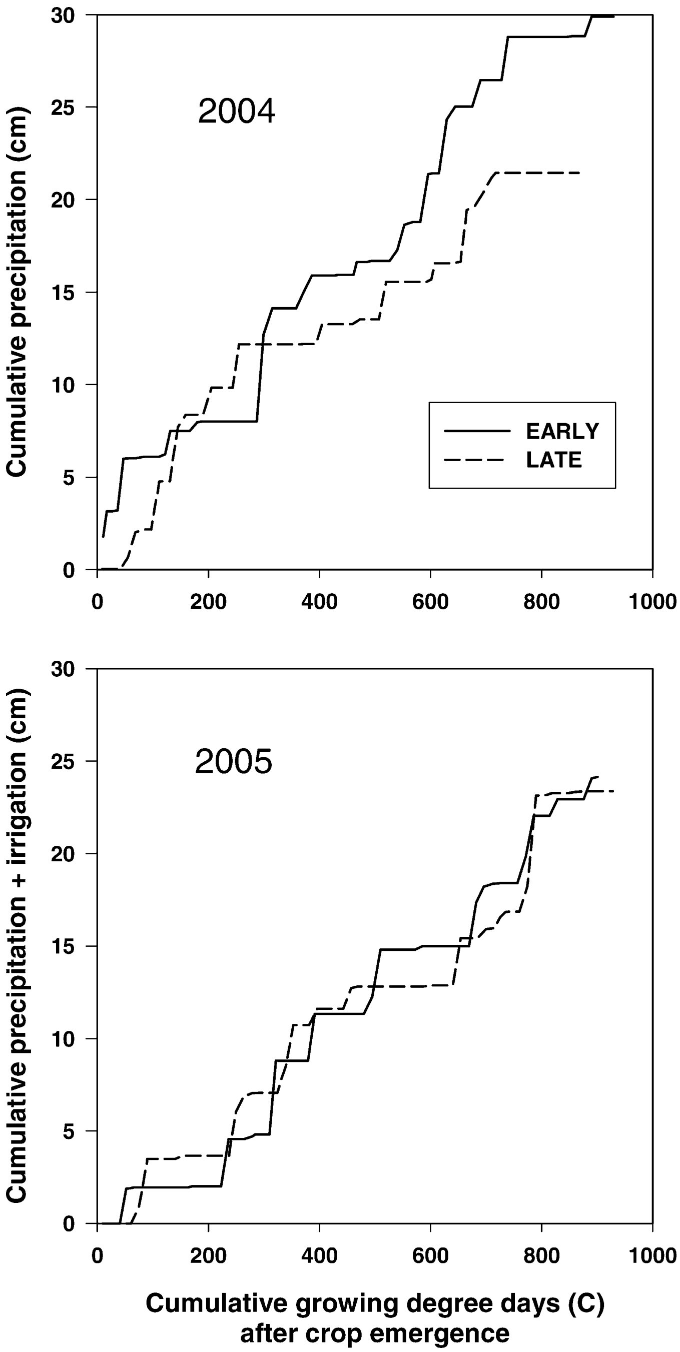

FIGURE 1. Cumulative precipitation (including irrigation in 2005) plotted against cumulative growing-degree days after crop emergence for two planting dates in 2004 and 2005 at Urbana, IL. Abbreviations: EARLY, sweet corn planted the first week of May; LATE, sweet corn planted the third week of June.

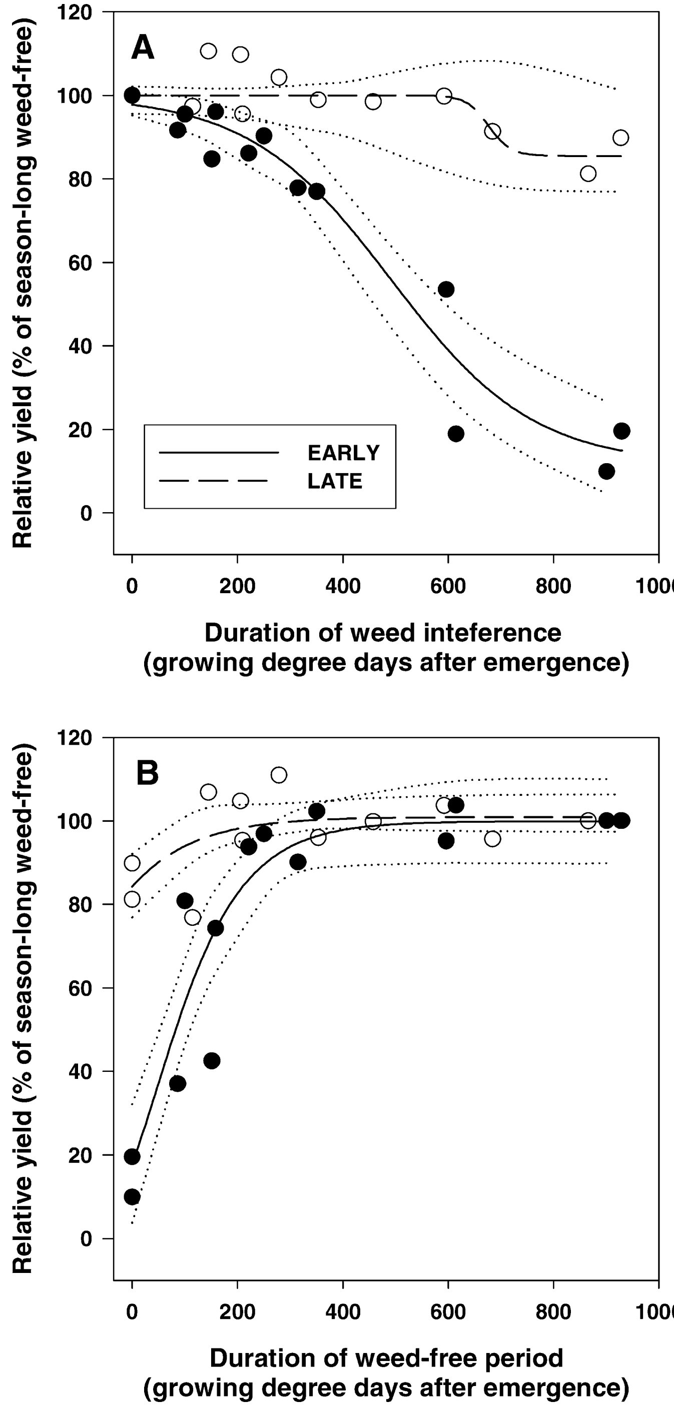

FIGURE 2. Sweet corn relative yield as a function of (A) increasing duration of weed interference, and (B) increasing duration of weed-free period, for two planting dates at Urbana, IL in 2004 and 2005. Solid and dashed lines predicted from fitting the three-parameter logistic model (Equation 1) and Gompertz model (Equation 2) were used to estimate the beginning and end of the critical period for weed control (CPWC), respectively. Dotted lines indicate 95% confidence intervals. Abbreviations: EARLY (filled circles), sweet corn planted the first week of May; LATE (open circles), sweet corn planted the third week of June; GDD, growing-degree days after crop emergence; and RMSE, root mean square error. Fitted equations for duration of interference are *relative yield* = [(1/{exp[0.007 × (GDD − 475.2)] + 1.13}) + [(1.13 − 1)/1.13]] × 100, RMSE = 16.0 for EARLY planting; and *relative yield* = [1/{exp[0.047 × (GDD − 635.2)] + 6.88}) + [(6.88 − 1)/6.88]] × 100, RMSE = 9.5 for LATE planting. Fitted equations for duration of weed-free period are *relative yield* = 99.92 × exp{−exp[−(*GDD* − 49.03)/90.88]}, RMSE = 21.9 for EARLY planting; and *relative yield* = 101.90 × exp{−exp[−(*GDD* − 168.27)/100.50]}, RMSE = 9.2 for LATE planting.

t is the length of the weed-free period after crop emergence (expressed in GDD), and b and k are constants.

Parameter estimates were determined using an iterative least-squares procedure (SigmaPlot 8.0[2]). Lack of fit was assessed by reporting root mean square errors (RMSE) and plotting 95% confidence intervals. The extra sum-of-squares principle for nonlinear-regression analysis (Ratkowsky 1983) was employed to evaluate the similarity of parameter estimates among years and planting dates. Comparisons were made by calculating a variance ratio of individual and pooled residual sums of squares. If parameter estimates were

Table 1. Mean weed density (with SE in parentheses) and species composition at Urbana, IL, for two planting dates measured in weedy experimental units at three growth stages of sweet corn.[a]

Year	Planting date	CGS	Total weed density	Species-specific contribution to weed density[b]					
				ABUTH	AMARE[c]	CHEAL	POROL	Grasses	Other
			No. m^{-2}	%					
2004	EARLY	VA	426 (225)	4	5	68	0	22	1
		V8	504 (212)	1	1	65	0	32	1
		R3	185 (35)	5	1	50	0	44	0
	LATE	V4	248 (26)	15	13	61	0	6	5
		V8	641 (99)	4	3	44	32	9	8
		R3	342 (139)	4	4	74	0	11	7
2005	EARLY	V4	158 (39)	2	14	63	18	0	3
		V8	286 (77)	0	38	39	20	2	1
		R3	191 (75)	2	57	36	2	0	3
	LATE	V4	111 (36)	1	14	7	66	3	9
		V8	278 (92)	0	6	15	63	7	9
		R3	86 (41)	0	14	22	42	4	18

[a] Abbreviations: EARLY, sweet corn planted the first week of May; LATE, sweet corn planted the third week of June; V4, corn with four visible collars; V8, corn with eight visible collars; R3, corn at sweet corn harvest.

[b] Weed species included grasses, which were predominantly barnyardgrass in 2004 and green foxtail in 2005; velvetleaf (ABUTH); redroot pigweed (AMARE); common lambsquarters (CHEAL); common purslane (POROL); and "Other," which included carpetweed, *Mollugo verticillata* L.; eastern black nightshade, *Solanum ptycanthum* Dun.; ivyleaf morningglory, *Ipomoea hederacea* (L.) Jacq.; jimsonweed, *Datura stramonium* L.; prickly side, *Sida spinosa* L.; and prostrate spurge, *Euphorbia humistrata* Engelm. ex Gray.

[c] Fewer than 5% of plants were common waterhemp, *Amaranthus rudis* Sauer.

constant across years or planting dates, data were pooled accordingly.

Model parameter estimates from Equations 1 and 2 were used to determine GDD corresponding to the beginning and end, respectively, of the CPWC at levels of yield loss of 2.5, 5.0, and 10%. For each CPWC component, GDD differed significantly between planting dates when 95% confidence intervals failed to overlap. Days after crop emergence (DAE) and crop growth stage (CGS) corresponding to the three levels of yield loss were included for additional reference.

Results and Discussion

Weed-free, sweet corn yields paralleled total precipitation of each environment. Weed-free yields (SE in parentheses) were 23.7 (0.4) and 16.9 (0.7) Mt ha^{-1} for EARLY and LATE planting dates, respectively, in 2004. The EARLY planting experienced 40% greater total precipitation in 2004, compared with LATE planting (Figure 1). Distributions of precipitation plus irrigation through 2005 were nearly identical among planting dates, and weed-free yields were 18.5 (1.1) and 18.6 (0.4) Mt ha^{-1} for EARLY and LATE planting dates, respectively.

Weeds began emerging within 2 d of crop emergence in all environments, and species were representative of common Corn Belt weeds. Total weed density was high, ranging from 248 to 426 plants m^{-2} at V4 in 2004 and 111 to 158 plants m^{-2} at V4 in 2005 (Table 1). At many sampling events, common lambsquarters was the most abundant weed species, with some exceptions; redroot pigweed and common purslane were abundant in 2005.

Despite high weed densities shortly after planting, weed canopy development varied by planting date. At the time of crop harvest, in 2004, weed canopy height was 176 cm in the EARLY planting compared with 52 cm in the LATE planting, and a similar trend was observed in 2005 (Table 2). An effect of planting date on weed populations was further evidenced by total weed biomass, where weed biomass was 500% or more in EARLY compared with LATE plantings at the time of crop harvest. Species contributing the most to total weed biomass were common lambsquarters, redroot pigweed, velvetleaf, common purslane, barnyardgrass in 2004, as well as green foxtail [*Setaria viridis* (L.) Beauv.] in 2005.

Duration of weed interference had a significant effect on sweet corn yield, with season-long weed interference resulting in 15% yield loss in LATE to 85% yield loss in EARLY (Figure 2A). The *F* test for comparing nonlinear models indicated sweet corn response to duration of weed interference was not consistent among planting dates for either year ($P < 0.001$ in both years). Additional *F* tests also indicated sweet corn response to duration of weed interference within planting date was consistent among years ($P = 0.12$ for EARLY; $P = 0.67$ for LATE). As a result, data were pooled by year within each planting date. Sweet corn planted EARLY was subjected to yield losses sooner and to a greater extent than sweet corn planted LATE. Therefore, the beginning of CPWC depended upon planting date. For EARLY planted sweet corn, the beginning of the CPWC based on 5% yield loss occurred by 160 GDD, corresponding to 18 DAE, when corn had four leaves (Table 3). In contrast, the same level of yield loss for LATE planting required 662 GDD, relating to 53 DAE, when corn was tasseling. Regardless of level of acceptable yield loss, weeds needed to be controlled several weeks earlier in sweet corn for an early May planting date compared with a mid-June planting date.

Duration of the weed-free period also had a significant effect on sweet corn yield (Figure 2B). The *F* test for comparing nonlinear models indicated sweet corn response to the duration of weed-free period was not consistent among planting dates for either year ($P < 0.001$ in both years). Additional *F* tests also indicated sweet corn response to the duration of the weed-free period within planting date was

Table 2. Mean weed height and oven-dry biomass (with SE in parentheses) and species composition at Urbana, IL, for two planting dates measured in weedy experimental units at three growth stages of sweet corn.[a]

Year	Planting date	CGS	Weed-canopy height	Total weed biomass	Species-specific contribution to oven-dry weed biomass[b]					
					ABUTH	AMARE[c]	CHEAL	POROL	Grasses	Other
			cm	g m^{-2}	%					
2004	EARLY	V4	5 (0)	6 (2)	19	4	38	0	39	0
		V8	23 (4)	83 (15)	6	1	36	0	57	0
		R3	176 (2)	647 (119)	10	0	10	0	79	1
	LATE	V4	1 (0)	1 (0)	46	8	34	0	10	2
		V8	7 (1)	17 (4)	13	4	23	42	12	6
		R3	52 (7)	120 (24)	23	10	46	0	11	10
2005	EARLY	V4	5 (0)	14 (4)	2	14	63	18	0	3
		V8	64 (6)	270 (42)	0	38	39	20	2	1
		R3	190 (15)	1,209 (127)	2	57	36	2	0	3
	LATE	V4	3 (0)	2 (2)	3	8	2	61	23	3
		V8	30 (1)	71 (33)	0	19	3	64	11	3
		R3	52 (11)	47 (27)	0	34	22	13	17	14

[a] Abbreviations: CGS, Crop growth stage; EARLY, sweet corn planted the first week of May; LATE, sweet corn planted the third week of June; V4, corn with four visible collars; V8, corn with eight visible collars; R3, corn at sweet corn harvest.

[b] Weed species included grasses, which were predominantly barnyardgrass in 2004 and green foxtail in 2005; velvetleaf (ABUTH); redroot pigweed (AMARE); common lambsquarters (CHEAL) common purslane (POROL); and "Other," which included carpetweed, eastern black nightshade, ivyleaf morningglory, jimsonweed, prickly side, and prostrate spurge.

[c] Fewer than 5% of plants were common waterhemp.

consistent among years ($P = 0.11$ for EARLY; $P = 0.15$ for LATE). As a result, data were pooled by year within each planting date. Sweet corn planted EARLY had to be maintained weed-free for a longer time than sweet corn planted LATE, as evidenced by the end of the CPWC. Based on 5% yield loss, the end of the CPWC occurred sooner in LATE planted sweet corn (134 GDD or V3) than in EARLY planted sweet corn (320 GDD or V8) (Table 3). Similar trends between EARLY and LATE were observed at other levels of yield loss.

The failure of high weed densities (> 100 m^{-2}) to cause severe yield loss in LATE-planted sweet corn indicated that planting date influenced the extent to which the crop had an advantage over the weed. The CPWC began sooner and ended later in EARLY planted sweet corn, indicating the crop was at a competitive advantage in LATE-planted sweet corn. A greater advantage in LATE-planted sweet corn was also evidenced by a shorter and less-dense weed canopy observed in LATE, relative to EARLY, planting (Tables 1 and 2). The mechanism by which sweet corn had a competitive advantage with delayed planting was likely the result of several environmental conditions favoring crop growth over weed growth. Photosynthetic pathway (C3 vs. C4) is an important factor in competitive interactions (Pearcy et al. 1981). Compared with EARLY planting, LATE-planted sweet corn experienced 3 to 5 more d when maximum air temperature exceeded 30 C (data not shown). Under these conditions, sweet corn, a C4 plant, would have higher photosynthetic rates and relative growth rate than common lambsquarters and velvetleaf, C3 plants that often dominated the study sites after planting (up to 80% of total weed biomass). Differential photoperiodic response between crops and weeds may have also been an advantage to the LATE crop. In soybean, Oliver (1979) reported velvetleaf was twice as competitive in mid-May, compared with late-June, planting and attributed the difference to a short-day photoperiodic response of velvetleaf.

Differences in CPWC due to planting date documented in this study highlight the need for a greater understanding of environmental factors affecting competition for limited resources. Deviation in site conditions (e.g., climate, production practices, and weed species) from this study would likely alter, to an unknown extent, planting date effects on CPWC. For example, competitive ability among three sweet corn hybrids has been conducted recently in Washington and Illinois. Although weed-free yields in Illinois averaged 57% of Washington yields, relative differences in crop tolerance and weed-suppressive ability among hybrids were often similar (R. A. Boydston and M. M. Williams II, unpublished data). Analysis of 19 site-years of competition studies indicated early temperature and midseason water balance largely determined the ability of dent corn to endure competitive stress from velvetleaf (McDonald et al. 2004).

A practical implication is that EARLY sweet corn requires more intensive weed management than LATE sweet corn, at least in the north-central United States. Given the weed species composition found in this research, sweet corn planted in mid-June required only a single weed-management event POST. In contrast, sweet corn planted in early May would likely require application of a PRE herbicide and possibly multiple POST tactics. Minimizing the use of soil-active herbicides, particularly in a late-planted crop, may be important for production of subsequent crops that are sensitive to herbicide residues. Moreover, because fewer weed-management interventions are necessary for LATE sweet corn, the cost of weed management should be less than EARLY sweet corn.

Sources of Materials

[1] Monosem NG Plus vacuum planter, A.T.I. Inc., 17135 West 116th Street, Lenexa, KS 66219.

[2] SigmaPlot 2002 for Windows, Version 8.02. SPSS, Inc. 444 North Michigan Avenue, Chicago, IL 60611.

TABLE 3. The critical period of weed control (CPWC) for sweet corn at two planting dates for three levels of yield loss (YL) expressed as growing-degree days (GDD), corresponding crop growth stage (CGS), and days after crop emergence (DAE).[a]

		CPWC by response variable								
		GDD[c]			DAE			CGS		
Component[b]	Planting date	2.5	5.0	10	2.5	5.0	10	2.5	5.0	10
		% YL								
Beginning of CPWC										
	EARLY	96 a	160 a	242 a	11	18	30	V2	V4	V6
	LATE	643 b	662 b	693 b	51	53	56	VT	VT	R1
End of CPWC										
	EARLY	386 b	320 b	254 b	37	31	26	V9	V8	V6
	LATE	207 a	134 a	61 a	15	10	5	V5	V3	V2

[a] Abbreviations: EARLY, sweet corn planted the first week of May; LATE, sweet corn planted the third week of June.

[b] Parameters determined from fitting a three-parameter logistic model (Equation 1) and Gompertz model (Equation 2) were used to estimate GDD, indicating the beginning and end of the CPWC, respectively.

[c] For each CPWC component, GDD estimates within a YL level followed by the same letter do not differ significantly among planting dates based on nonoverlapping 95% confidence intervals.

Acknowledgments

I appreciate the technical expertise of John Frihauf and Ryan Hasty and the assistance from students Brian Philiben, Nathan Smith, and Yim So.

Literature Cited

Azanza, F., A. Bar-Zur, and J. A. Juvik. 1996. Variation in sweet corn kernel characteristics associated with stand establishment and eating quality. Euphytica. 87:7–18.

Buhler, D. D. and J. L. Gunsolus. 1996. Effect of date of preplant tillage and planting on weed populations and mechanical weed control in soybean (*Glycine max*). Weed Sci. 44:373–379.

Dyck, E. and M. Liebman. 1994. Soil fertility management as a factor in weed control: the effect of crimson clover residue, synthetic nitrogen fertilizer, and their interaction on emergence and early growth of lambsquarters and sweet corn. Plant Soil 167:227–237.

Evans, S. P., S. Z. Knezevic, J. L. Lindquist, C. A. Shapiro, and E. E. Blankenship. 2003. Nitrogen application influences the critical period for weed control in corn. Weed Sci. 51:408–417.

Gower, S. A., M. M. Loux, J. Cardina, and S. K. Harrison. 2002. Effect of planting date, residual herbicide, and postemergent application timing on weed control and grain yield in glyphosate-tolerant corn. Weed Technol. 16:488–494.

Hall, M. R., C. J. Swanton, and G. W. Anderson. 1992. The critical period of weed control in grain corn (*Zea mays*). Weed Sci. 40:441–447.

Hassell, R. L., R. J. Dufault, and T. L. Phillips. 2003. Low-temperature germination response of *su*, *se*, and sh_2 sweet corn cultivars. HortTechnol. 13:136–141.

Knezevic, S. Z., S. P. Evans, E. E. Blankenship, R. C. Van Acker, and J. L. Lindquist. 2002. Critical period for weed control: the concept and data analysis. Weed Sci. 50:773–786.

McDonald, A. J., S. J. Riha, and C. L. Mohler. 2004. Mining the record: historical evidence for climatic influences on maize-*Abutilon theophrasti* competition. Weed Res. 44:439–445.

Oliver, L. R. 1979. Influence of soybean (*Glycine max*) planting date on velvetleaf (*Abutilon theophrasti*) competition. Weed Sci. 27:183–188.

Pearcy, R. W., N. Tumosa, and K. Williams. 1981. Relationships between growth, photosynthesis and competitive interactions for a C_3 and a C_4 plant. Oecologia. 48:371–376.

Rajcan, I. and C. J. Swanton. 2001. Understanding maize–weed competition: resource competition, light quality and the whole plant. Field Crops Res. 71:139–150.

Ratkowsky, D. A. 1983. Pages 135–157 *in* Nonlinear Regression Modeling: A Unified Practical Approach. New York: Marcel Dekker.

Ritchie, S. W., J. J. Hanway, G. O. Benson, and J. C. Herman. 2003. How a corn plant develops. Special Report No. 48 (Revised). Ames, IA: Iowa State University of Sciences and Technology, Cooperative Extension Service.

Rushing, G. S. and L. R. Oliver. 1998. Influence of planting date on common cocklebur interference in early maturing soybean. Weed Sci. 46:99–104.

Treat, C. L. and W. F. Tracy. 1994. Endosperm type effects on biomass production and on stalk and root quality in sweet corn. Crop Sci. 34: 396–399.

Vengris, J., W. G. Colby, and M. Drake. 1955. Plant nutrient competition between weeds and corn. Agron. J. 47:213–216.

Williams, M. M. II and J. B. Masiunas. 2006. Functional relationships between giant ragweed (*Ambrosia trifida* L.) interference and sweet corn yield and ear traits. Weed Sci 54:947–952.

Zimdahl, R. L. 2004. Pages 109–130 *in* Weed–Crop Competition: A Review. Oxford, UK: Blackwell Publishing.

Received January 4, 2006, and approved May 8, 2006.