Intraspecific and Interspecific Competition in Sweet Corn

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ABSTRACT

Competition among crop plants (i.e., intraspecific) and between crop and weed plants (i.e., interspecific) likely co-occurs in many sweet corn (*Zea mays* L.) fields; however, a fundamental understanding of the extent to which the crop is affected by the combination of these stresses is unknown. The objective of this work was to identify the extent to which seeding level influences the crop's tolerance to weed competition in terms of crop development, yield, and profitability. In field research in Illinois and Washington, two hybrids with different levels of tolerance to weed competition were planted each of 2 yr at five seeding levels each year and grown in the presence and absence of wild-proso millet (*Panicum miliaceum* L.). The crop's ability to tolerate intraspecific and interspecific competition was additive, as evidenced by no significant interaction between seeding level and weed competition for thermal time to mid-silk, marketable ear number, marketable ear mass, and gross profit margin to the processor. Losses in gross profit margin due to weed competition alone ranged from \$2,400 to \$8,100 ha^{-1}. Hybrids used in this work showed differential tolerance to interspecific competition, but of the seeding levels tested, neither hybrid was consistently more tolerant to intraspecific competition. Across years and hybrids, the seeding level that consistently did not delay silking but maximized marketable ear number, marketable ear mass, and gross profit margin to the processor was 70,000 and 88,200 ha^{-1} in Illinois and Washington, respectively. Improving weed management efficacy and genetic tolerance to competition offer two approaches to improving sweet corn productivity.

The ability of corn to tolerate intense competition between crop plants (i.e., intraspecific competition) has improved dramatically over the last century. A combination of genetic improvements and superior management has raised the ability to seed field corn from population densities below 30,000 plants ha^{-1} in the 1930s (Duvick, 2005) to more than 100,000 plants ha^{-1} in the last decade (Stanger and Lauer, 2006). Field corn population densities have increased at an average rate of 1000 plants ha^{-1} yr^{-1} over the last 50 yr in the Midwest (Duvick, 2005).

While plant population densities also have increased in sweet corn production in the last century, tolerance to intraspecific competition remains less than field corn. Plant population densities used for a popular sweet corn hybrid released in the 1930s (i.e., Golden Cross Bantam) was about 7000 plants ha^{-1} (Mack, 1972). A recent survey of sweet corn grown for processing in the Midwest revealed an average population density of 56,000 plants ha^{-1} (Williams, 2012). Field research in Illinois indicated certain hybrids could be planted at an additional 12,000 plants ha^{-1} than currently used to maximize gross profit margin to the processor (Williams, 2012).

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Corn's ability to tolerate intense competition with weeds (i.e., interspecific competition) is also important in modern production systems. Growers spend on average \$123 ha^{-1} controlling weeds in sweet corn, with heavy reliance on a small number of preemergence and postemergence herbicides (Williams et al., 2010). Nonetheless, nearly all sweet corn fields surveyed have weeds that escape management and a majority of those fields suffer yield loss due to weed competition (Williams et al., 2008). More than 50 species of grass and broadleaf weeds are problematic in sweet corn. Wild-proso millet is one of the most abundant species throughout production areas of North America where sweet corn is grown for processing (Williams et al., 2008).

Commercial sweet corn hybrids respond differently to competition. Hybrid variability in intraspecific competition is evidenced by a 22,000 plant ha^{-1} difference in population densities necessary to optimize yield of commonly grown sweet corn hybrids (Williams, 2012). Likewise, not all sweet corn hybrids tolerate interspecific competition the same. Among 25 commercial sweet corn hybrids tested, So et al. (2009) reported that weed competition reduced ear mass 24 to 82%, depending on the hybrid. Zystro et al. (2012) found that traits conferring sweet corn tolerance to weed competition are heritable and proposed breeding efforts to improve the crop's competitive ability with weeds.

Intraspecific and interspecific competition likely co-occurs in sweet corn. The extent to which the cumulative effects of intraspecific and interspecific competition influence sweet corn growth and yield is unknown. For instance, does tolerance to interspecific competition mirror tolerance to intraspecific competition? From a practical standpoint, should a hybrid with superior tolerance to weeds be planted at a higher seeding level than a

Abbreviations: GDD, growing degree days.

hybrid with poor tolerance? Answering these questions requires evaluating not only sweet corn yield in field experiments, but also quantifying the impact of intraspecific and interspecific competition on profitability to the processor. The objective of this work was to identify the extent to which seeding level influences the crop's tolerance to weed competition in terms of crop development, yield, and profitability. Two hybrids known to vary in tolerance to weed competition were tested.

MATERIALS AND METHODS

Field experiments were conducted in 2008 and 2009 near Urbana, IL (40°4′ N, 88°12′ W) and Prosser, WA (46°15′ N, 119°44′ W). The soil at Illinois was a Flanagan silt loam (fine, smectitic, mesic Aquic Argiudoll) averaging 3.7% organic matter and pH of 6.0. The soil at Washington was a Warden loam (coarse-silty, mixed, superactive, mesic Xeric Haplocambid) averaging 1.3% organic matter and pH of 7.0. Experiments were located in different fields each year. The previous crop was soybean and field corn in Illinois and Washington, respectively. Based on soil test recommendations in Illinois, 135 and 129 kg N ha^{-1} were applied as urea 17 Apr. 2008 and 24 Mar. 2009, respectively. In Washington, 280 and 168 kg N ha^{-1} were applied as urea 30 Apr. 2008 and 1 May 2009, respectively. Urea was incorporated within a day of application using a field cultivator or chisel/packer. The experimental sites were chisel plowed in the fall, followed by one pass each of a disk harrow and field cultivator before planting. Planting dates were 29 May 2008 and 1 June 2009 in Illinois, and 7 May 2008 and 8 May 2009 in Washington. Consistent with standard sweet corn production practices, rainfall was supplemented with sprinkler irrigation to facilitate crop growth at both locations.

Experimental Approach

The treatment design was a 2 × 5 × 2 factorial of hybrid × seeding level × weed competition. Treatments were arranged in a split-split plot experimental design with four replications. Main plot treatments consisted of two shrunken-2 endosperm-type sweet corn hybrids, specifically Optimum (Crookham Company, Caldwell, ID) and Overland (Rogers Seeds/Syngenta, Boise, ID). Previous research showed that Overland had approximately threefold greater tolerance to weed competition than Optimum (So et al., 2009). Main plots were blocks of 20 rows spaced 76-cm apart and 18.3 m in length. Seeding level was the subplot treatment, whereby one of five seeding levels was randomly assigned to four-row by 18.3 m-long subplots. Seeding level was imposed at planting by modifying the planter drive assembly to achieve specific seed delivery rates (Table 1). Seeding levels were chosen in an attempt to capture crop response across suboptimal and supra-optimal plant populations. Seeding levels in Washington ranged from 57,600 to 138,800 seed ha^{-1} in 2008. Seeding levels were lowered to 41,300 to 120,300 seed ha^{-1} in 2009 to more adequately capture crop response to suboptimal plant populations. Each subplot was divided such that weedy and weed-free treatments were randomly assigned to four-row by 9.2 m-long sub-subplots. The weedy treatment was created by overseeding wild-proso millet (~100 seed per meter of row) approximately 1-cm deep directly in the center two crop rows of appropriate sub-subplots using a cone planter at the time of corn seeding. The weed-free treatment was created by applying a preemergence application of *S*-metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide). Weeds other than wild-proso millet were not uniformly distributed throughout the study area; therefore, they were controlled in weedy and weed-free plots with a preemergence application

Table 1. Details of the planters used and seeding levels for sweet corn studies conducted over 2 yr near Urbana, IL, and Prosser, WA.

Site	Year	Planter make	Planter model	Plate no.	Seeding level	Driver	Driven	Seed delivery rate
								no. ha^{-1}
IL	2008	Monosem	NG+	1837	1	14	28	35,000
					2	19	28	52,500
					3	24	26	70,000
					4	26	23	87,500
					5	24	17	105,000
	2009	Monosem	NG+	1837	1	14	28	35,000
					2	19	28	52,500
					3	24	26	70,000
					4	26	23	87,500
					5	24	17	105,000
WA	2008	Kinze	MT	–	1	16	18	57,600
					2	30	22	88,200
					3	22	14	102,200
					4	26	14	120,300
					5	30	14	138,800
	2009	Kinze	MT	–	1	14	22	41,300
					2	26	28	60,000
					3	30	22	88,200
					4	22	14	102,000
					5	26	14	120,300

of atrazine (6-chloro-*N*-ethyl-*N*¢-(1-methylethyl)-1,3,5-triazine-2,4-diamine), rotary hoeing at crop emergence, interrow cultivation before canopy closure, and handweeding, as needed.

Data Collection

Growing degree days (GDD) were determined using a base temperature of 10°C and daily temperature data from a weather station located within 1 km of the experiments (Illinois State Water Survey, Champaign, IL, and Washington Agricultural Weather Network, Prosser, WA). Using plants in the center two rows of each sub-subplot, the number of plants with emerged silks were counted daily from the onset of anthesis until at least 50% of plants had silked; herein identified as the mid-silk date. Thermal time to mid-silk was calculated as the cumulative GDD from crop emergence to mid-silk date. Harvest of each hybrid was based on crop development in the lowest seeding level and weed-free treatment, approximately 18 d after mid-silk. Marketable ears measuring $\geq$ 4.5 cm in diameter were hand-harvested from the center two rows over a 6.1-m length. Marketable ear number and ear mass were recorded. In Illinois, samples of ears were husked with a husking bed (A&K Development, Eugene, OR), kernels were removed with a hand-fed corn cutter (A&K Development, Eugene, OR), and kernel mass yield was recorded. Hybrid-specific kernel mass yield was predicted for plots based on linear regression analysis of sampled ear mass and kernel mass (r^2 = 0.957).

Sweet corn is often grown under contract, particularly when grown for processing. Processors provide seed of specific hybrids to growers, who are compensated based on the mass of ears harvested from the field. An economic analysis was used to quantify the processor's gross profit margin in relation to sweet corn seeding level, hybrid, and weed competition. Gross return was the product of predicted kernel mass yield, kernel mass per case, and wholesale cash price of canned sweet corn. Contract cost was the product of ear mass yield and grower cash rate. Sweet corn seeding level cost was the product of the planter's seed delivery rate and seed cost. Kernel mass per case (6.13 kg case^{-1}), wholesale cash price of canned sweet corn ($12 case^{-1}), grower cash rate ($110 Mt^{-1}), and seed cost ($3 per 1000 kernels) were obtained from sweet corn seed and processing industries (George Crookham, Crookham Company; Nick George, Midwest Food Processors Association; personal communication, 2011). Gross profit margin to the processor was gross return minus contract cost and seeding level cost.

Data Analysis

Seeding level was considered a categorical treatment because levels are based on planter assembly settings, which did not allow for a continuous treatment variable. Seeding levels varied by location and year; therefore, data were analyzed separately by location and year. Diagnostic tests of residuals were used to determine if transformation of data were necessary. Ear mass, ear number, and gross profit margin complied with the ANOVA assumption of homogeneity after a square root transformation. Despite exploring several types of transformations of mid-silk data, none were found to meet ANOVA assumptions; therefore, mid-silk data were not transformed. Data were analyzed using the Mixed procedure in SAS (SAS Institute, 2008). Fixed effects included seeding level, hybrid, and weed competition, along with their interactions. Random effects included replicate and interactions with replicate. Where only main effects were significant, means were compared using protected, Bonferroni-corrected multiple comparisons (Neter et al., 1996). For ease of interpretation, means of non-transformed data are presented.

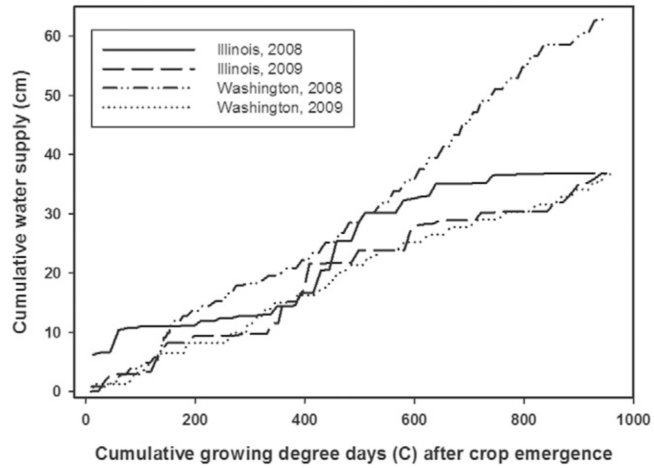

Fig. 1. Cumulative water supply (rainfall plus irrigation) plotted against cumulative growing degree days after crop emergence for field experiments in Illinois and Washington in 2008 and 2009.

RESULTS

Seasonal Conditions

Water supply (i.e., rainfall plus irrigation) varied within a season and across site-years. Total water supply from crop emergence to harvest for most site-years averaged 36.8 cm (Fig. 1). The exception was Washington in 2008, which received 62.8 cm of water. Approximately 1 mo after crop emergence, wild-proso millet density averaged 66 and 133 plants m^{-2} in Illinois (2008 and 2009, respectively) and 61 and 38 plants m^{-2} in Washington (2008 and 2009, respectively).

Thermal Time to Mid-Silk

Depending on site-year, thermal time to mid-silk was influenced by the main effects of crop hybrid, seeding level, and weed competition ($p \leq 0.020$), but none of their interactions were significant ($p \geq 0.101$). Reproductive development differed by hybrid, with Overland requiring an additional 66 to 96 GDD from emergence to mid-silk, compared to Optimum (Table 2). Under normal conditions, this difference in GDD equates to 5 to 7 d in Illinois and 7 to 10 d in Washington. Weedy treatments delayed thermal time to mid-silk 37 to 86 GDD (3– 9 d) in 2 of 4 site-years. Thermal time to mid-silk was not delayed by the first three seeding levels, but often was delayed by higher seeding levels (Table 3).

Marketable Ear Number and Mass

Marketable ear number was influenced by the interaction of hybrid and weed competition in 3 of 4 site-years ($p \leq 0.052$). The weedy treatment resulted in a greater loss of marketable ears in Optimum (17–49% of weed-free), compared to Overland (24–64% of weed-free) (Table 2). One exception was in Illinois in 2008, when weed competition appeared to be low, as evidenced by weedy yield averaging 84% of weed-free yield.

With regards to the effects of crop hybrid, weed competition, and their interaction, marketable ear mass mainly was affected by

Table 2. Thermal time from crop emergence to mid-silk measured in growing degree days (GDD), number of marketable ears, marketable ear mass, and processors' gross profit margin of two sweet corn hybrids (H) as influenced by presence or absence of wild-proso millet competition (C). *P* values from analysis of variance are shown below means of five seeding levels and four replications.

Site	Year	Crop hybrid	Weed competition	Thermal time to mid-silk	Marketable ear no.	Marketable ear mass	Gross profit margin
				GDD	boxes ha^{-1}	Mt ha^{-1}	\$ ha^{-1}
IL	2008	Optimum	weed-free	582	1143	15.7	9,835
			weedy	585	976	11.8	7,367
		Overland	weed-free	680	970	16.6	10,420
			weedy	680	793	12.9	8,066
			H	<0.001	0.008	0.182	0.182
			C	0.566	<0.001	<0.001	<0.001
			H × C	0.526	0.864	0.937	0.937
	2009	Optimum	weed-free	636	1061	12.9	8,079
			weedy	739	215	2.0	1,099
		Overland	weed-free	720	858	11.8	7,355
			weedy	788	291	3.4	1,953
			H	0.009	0.383	0.956	0.956
			C	<0.001	<0.001	<0.001	<0.001
			H × C	0.110	<0.001	<0.001	0.002
WA	2008	Optimum	weed-free	563	1289	16.2	10,112
			weedy	603	220	2.4	1,262
		Overland	weed-free	636	957	14.3	8,846
			weedy	670	231	2.6	1,385
			H	0.005	0.279	0.652	0.652
			C	<0.001	<0.001	<0.001	<0.001
			H × C	0.477	0.001	0.115	0.115
	2009	Optimum	weed-free	524	1190	18.8	11,838
			weedy	540	580	7.4	4,515
		Overland	weed-free	609	1035	17.7	11,096
			weedy	611	658	9.8	6,062
			H	<0.001	0.577	0.564	0.565
			C	0.101	<0.001	<0.001	<0.001
			H × C	0.192	0.052	0.080	0.080

weed competition. Yield loss due to the weedy treatment ranged from a low of 23% in Illinois in 2008, to a high of 83% the same year in Washington (Table 2). The weedy treatment resulted in a greater loss of marketable ear mass in Optimum (16% of weed-free), compared to Overland (29% of weed-free) in Illinois in 2009.

Seeding level one consistently produced among the lowest number of marketable ears, whereas seeding levels three and four consistently produced among the highest number of marketable ears (Table 3). Crop hybrid and seeding level often had an interactive effect on crop yield; however, no consistent pattern in the interaction was observed across site-years.

Different trends were observed for marketable ear mass. Across sites, years, and hybrids, seeding levels two and three were always among the highest yields (Table 3). Seeding levels one and five resulted in the most variable yields.

Gross Profit Margin

Weed-free gross profit margin to the processor averaged \$8923 ha^{-1} in Illinois and \$10,473 ha^{-1} in Washington. Gross profit margin was reduced 24 to 86% by weedy treatments, depending on site-year (Table 2). In only one case was weed-mediated yield loss affected by hybrid; in Illinois in 2009 weedy yields were 14 and 27% of weed-free yields for Optimum and Overland, respectively.

Regional differences were observed in seeding levels that maximized gross profit margin. For instance, seeding level three (70,000 seed ha^{-1}) was the single level that resulted in maximum gross profit margin across years and hybrids in Illinois (Table 3). In contrast, gross profit margin remained high across a range of seeding levels (up to 102,000 seed ha^{-1}) in Washington.

DISCUSSION

The crop's ability to tolerate intraspecific and interspecific competition was additive, as evidenced by no significant interaction between seeding level and weed competition for any of the response variables measured in this work. As a result, the effect of seeding level on sweet corn development, yield, and profitability was not affected by weed competition, and the effect of weed competition on these response variables was not affected by seeding level. The combined effect of intraspecific and interspecific competition is similar to previous research examining multiple stresses in corn. The effect of weed competition or drought stress, in combination with maize dwarf mosaic infection, was additive during the vegetative stage of sweet corn growth (Olson et al., 1990; Williams and Pataky, 2012). Weed competition in combination with water and nutrient stress resulted in an additive, not synergistic, decline in field corn biomass at maturity (Page et al., 2011).

Table 3. Thermal time from crop emergence to mid-silk measured in growing degree days (GDD), number of marketable ears, marketable ear mass, and processors' gross profit margin of two sweet corn hybrids as influenced by crop seeding level. Within each site-year, means (of two weed competition levels and four replications) within a column followed by the same lower-case letter are not significantly different at $p \leq 0.05$ as determined by Bonferroni-corrected multiple comparisons. Hybrid means that differ within a site-year are identified with a dagger (†).

Site	Year	Seeding level	Thermal time to mid-silk	Marketable ear no.		Marketable ear mass		Gross profit margin	
				Optimum	Overland	Optimum	Overland	Optimum	Overland
			GDD	boxes ha^{-1}		Mt ha^{-1}		\$ ha^{-1}	
IL	2008	1	623b	840b	702b	12.4b	13.3b	7,867b	8,414b
		2	629b	942b	786b	13.0ab	14.3ab	8,157ab	9,024b
		3	628b	1109a	1009a	14.3ab	16.8a	8,953ab	10,537a
		4	635ab	1179a	929a	14.7a	15.0ab	9,148a	9,354b
		5	643a	1230a	982a	14.4ab	14.4ab	8,880ab	8,899b
	2009	1	698b	509b	595a	6.7a	9.1a	4,169a	5,725a
		2	695b	657a	568a	8.0a	8.2ab	4,972a	5,131ab
		3	733ab	638a	670a	7.8a	8.5ab	4,773a	5,245a
		4	736a	694a	581a	7.7a	6.9b	4,661a	4,152b
		5	740a	†694a	†458b	7.3a	5.4c	4,371a	3,168c
WA	2008	1	611a	739ab	563a	10.8a	8.8a	6,760a	5,488a
		2	615a	894a	597a	11.3a	8.8a	6,997a	5,349a
		3	618a	877a	580a	9.9a	8.5a	6,016a	5,163a
		4	624a	706b	611a	8.7ab	8.2a	5,249b	4,912a
		5	621a	557b	619a	6.0b	7.9a	3,412b	4,668a
	2009	1	566c	†202b	†648b	†3.2b	†12.2a	†1,943b	†7,669a
		2	557c	984a	849ab	15.7a	15.7a	9,918a	9,863a
		3	569bc	1079a	936a	17.0a	14.2a	10,616a	8,871a
		4	577ab	1127a	886ab	16.3a	13.6a	10,144a	8,446a
		5	585a	1031a	914a	13.4a	13.1a	8,262a	8,046a

The extent to which the weedy treatment affected the crop was determined by the severity of weed competition, which varied by site-year. Weed species and population densities also vary widely among growers' fields. Based on field surveys conducted in Illinois, Minnesota, and Wisconsin, 43% of fields were unaffected by weeds persisting until harvest, whereas 11% of fields suffered yield losses exceeding 20% (Williams et al., 2008). These experiments reflect conditions when weeds are poorly controlled and interspecific competition is greatest. Presence of weed species does not necessarily reduce crop yield; however, weed populations sufficient to cause even small delays in crop development have large effects on sweet corn. Relative to the weed-free control, a 2-d delay in silk emergence due to giant ragweed (*Ambrosia trifida* L.) competition corresponded to a 37% reduction in marketable ear mass (Williams, 2010). In the present work, losses in gross profit margin due to weed competition ranged from \$2400 to \$8100 ha^{-1}.

Hybrids used in this work showed differential tolerance to weed competition, consistent with previous research on these hybrids (So et al., 2009). For instance, Optimum suffered greater weed competition-mediated losses of marketable ear number and ear mass than Overland. Surprisingly, hybrids did not differ in tolerance to intraspecific competition. Ear mass yield was similar between hybrids ($p \geq 0.182$) and the interaction among hybrid, seeding level, and weed competition was not significant ($p \geq 0.263$). Based on any single response variable measured in this work, neither hybrid was consistently more tolerant to seeding level across site-years. These results suggest hybrid tolerance to intraspecific competition does not necessarily reflect tolerance to interspecific competition. Why not? Page and others (2010b) proposed the physiological mechanisms through which yields are reduced from interspecific and intraspecific competition may be common to both. After all, critical resources needed for crop development (e.g., light, water, and nutrients) are often limited and intense competition from neighbors reduces yields, regardless of whether those neighbors are conspecific (Boomsma et al., 2009; Rossini et al., 2011) or not (Lindquist et al., 1998). More recently, a resource independent process, specifically a shade avoidance response in field corn, was found to play a major role in crop competitiveness (Page et al., 2010a). Shade avoidance alone has minimal effect on field corn productivity, but in combination with abiotic stresses, creates the potential for yield loss (Page et al., 2010b). However, there exists considerable variability among genotypes in terms of light quality sensitivity in several crops, including rice (*Oryza sativa* L.) (Merotto et al., 2009), wheat (*Triticum aestivum* L.) (Casal, 1988), and field corn (Maddonni et al., 2002). Given the inconsistent hybrid responses to interspecific and intraspecific competition observed in the present work, it is reasonable to hypothesize somewhat different resource dependent or independent processes are engaged for each hybrid.

Sweet corn yield response to seeding levels is consistent with recent research examining the effect of plant population density on processing sweet corn. Time to silk emergence generally increased with seeding level and is consistent with an approximate 5 GDD delay in silk emergence for each additional plant m^{-2} (Williams, 2012). Across sites, years, and hybrids, seeding levels two and three always resulted in the highest yields. For Illinois, these two seeding levels equate to 52,500 and 70,000 plants ha^{-1}, respectively. Among processing hybrids used commonly in the Midwest, optimal plant population densities were found to range from 48,100 to 70,100 ha^{-1} (Williams, 2012).

A regional effect on crop performance was observed. Seeding levels that maximized yield and profit differed between Illinois and Washington. For instance, 70,000 seed ha^{-1} was the highest seeding level that consistently maintained gross profit margin for both hybrids in Illinois. In contrast, gross profit margin for both hybrids remained high at seeding levels up to 102,000 seed ha^{-1} in Washington. This observation is generally consistent with sweet corn production practices within each region, with regards to the Pacific Northwest having higher plant populations than the Midwest (authors' observations, 2007). Environmental conditions in Washington are typically better for crop growth than Illinois, as evidenced by an average 48% higher state-wide yield of sweet corn grown for processing in Washington (Anonymous, 2011). Improvement in corn yield per unit area is directly linked to being able to grow corn successfully at high plant population densities (Duvick, 2005).

Due to incomplete weed control in most fields and a desire on behalf of growers and processors to maximize yield per unit area, intraspecific and interspecific competition likely co-occurs in sweet corn. These two stresses have an additive effect on crop development and yield, the extent to which is driven by the crop population density and competitiveness of the weed community. Of the seeding levels tested, results did not support the hypothesis that a hybrid with superior tolerance to weeds could be planted at a higher seeding level than a hybrid with poor tolerance. Across years and hybrids, the seeding level that consistently did not delay silking but maximized marketable ear number, marketable ear mass, and gross profit margin to the processor was 70,000 and 88,200 ha^{-1} in Illinois and Washington, respectively. Results also show considerable improvements can be made in sweet corn productivity. Identifying economically viable approaches to reduce the widespread occurrence of weed competition likely will require a combination of diverse weed management tactics including tolerance to weed competition. Given the poor genetic tolerance to intraspecific competition relative to field corn, coupled with the need to increase plant populations to improve yield, sweet corn breeding programs are likely to aim for higher tolerance to intense intraspecific competition.

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