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Few crop traits accurately predict variables important to productivity of processing sweet corn

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ABSTRACT

Recovery, case production, and gross profit margin, hereafter called 'processor variables', are as important metrics to processing sweet corn as grain yield is to field corn production. However, crop traits such as ear number or ear mass alone are reported in sweet corn production research rather than processor variables. The objective of this research was to determine the extent to which certain crop traits could be used to predict variables important to productivity of sweet corn grown for processing. The data used in this research reflected 22 different growing environments over an 8-year period representing 31 processing hybrids. Relations between processor variables and 17 crop traits (5 plant traits, 8 ear traits, and 4 yield traits) were characterized. None of the crop traits adequately predicted recovery, defined as the percentage of green ear mass (i.e. complete ears with husk leaves) represented by fresh kernel mass. Case production, defined as cases of kernels per unit area, was strongly associated ($\rho \geq 0.869$) with ear number, green ear mass, husked ear mass, and fresh kernel mass. Similar correlations ($\rho \geq 0.854$) were found between the yield traits and gross profit margin, defined as the value of case production less the contracted cost of green ear mass. However, regression analyses of relationships between processor variables and individual yield traits showed that fresh kernel mass was by far the best predictor of case production and gross profit margin. While ear number or green ear mass are commonly reported in field research of processing sweet corn, relevancy of the research would be enhanced if fresh kernel mass were measured and reported.

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1. Introduction

Applied research aimed at improving crop productivity is predicated on the ability to accurately measure important crop responses, such as yield, in field tests. Historically for many agronomic crops including field corn (*Zea mays* L.), grain yield at physiological maturity is the primary response variable used to identify superior crop production practices and guide germplasm improvement (Duvick, 2005). Moreover, research equipment has long been available, and is continually improved upon, which aids both public and private researchers in collecting data on grain yield.

Response variables other than grain yield are more important in certain field crops. For instance, sweet corn is not harvested at physiological maturity, but during a narrow window of time at the R3 stage (crop stages defined by Abendroth et al., 2011); approximately 72–76% kernel moisture, depending on endosperm mutation. Furthermore, sweet corn is grown for two markets – fresh market and processing (Tracy, 1993). Fresh market sweet corn for shipping is wholesaled by ear number, such as 50-ear boxes. Processing sweet corn is grown under contract, whereby the processor makes several crop management decisions, including but not limited to hybrid, planting date, and plant population density (Nick George, Midwest Food Processors Association, pers. comm.). Typically, the processor pays the grower a specific rate based on mass of green ears produced per unit area. Therefore, the metric important to the grower of processed sweet corn is green ear mass (i.e. ears with husk leaves), often expressed as $Mt\,ha^{-1}$. However, the metric important to the sweet corn processor is cases of kernels (canned or frozen) per contracted field, often expressed as cases ha^{-1}, and hereby referred to as case production.

Throughout the developed world, commercial production of processing sweet corn is extensively mechanized, utilizing self-propelled harvesters and largely automated processing facilities (Brian Maul, Oxbo International, pers. comm.). However, unlike field corn, mechanization of sweet corn harvest and processing in field plot research is rare. Nearly all public and private research programs hand-harvest experimental field plots (author, pers. obs.). Very few public programs, and not all private programs, have the ability to husk green ears or cut fresh kernels from the cob; labor requirements are even higher for those programs with access to

Abbreviations: CGS, crop growth stage; GDD, growing degree day; IPAR, intercepted photosynthetically active radiation; LAI, leaf area index.

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appropriate equipment (namely a husking bed and corn cutter). As such, lack of field plot harvesters, high labor costs, and time constraints at harvest place major limitations on sweet corn research, relative to field corn. For instance, the most recent field research on processing sweet corn does not report case production in studies of plant pathology (Clough et al., 2011), fertility management (Johnson et al., 2012), weed control (Johnson et al., 2010; Williams et al., 2011), and sweet corn breeding and genetics (Assunção et al., 2010; Solomon et al., 2012). Ear number or green ear mass are often the only crop responses reported in research on field productivity of processing sweet corn. Sometimes, other crop responses are reported, including plant traits (e.g. height or canopy density) or ear traits (e.g. ear length or ear width).

There may be a disconnect in the data reported in field research, and the data needed by the seed and processing industries to improve sweet corn production. Ear number is largely insignificant to the processor. Green ear mass does not directly characterize case production. How ear traits relate to sweet corn yield is unreported. Sweet corn processors utilize different variables to help make decisions about field production, hereafter collectively called 'processor variables'. In addition to case production, recovery, defined as the percentage of green ear mass represented by fresh kernel mass, is important. A higher recovery results in less plant material (i.e. primarily husks, cobs, and shanks) going through the processing facility and less waste requiring disposal. Finally, gross profit margin quantifies economic productivity of field operations. Gross profit margin is calculated as the value of case production per unit area less the contracted cost of green ear mass per unit area. In order to directly quantify these processor variables in field research, researchers need to husk ears and cut kernels.

Given the time and cost of measuring fresh kernel mass in field research, is it actually necessary? Perhaps ear number, green ear mass, or a different crop trait, adequately relates to processor variables. Therefore, the objective of this work was to determine the extent to which certain crop traits could be used to predict variables important to productivity of sweet corn grown for processing.

2. Materials and methods

2.1. Data

Data were compiled from previously published field studies on sweet corn (Williams, 2006, 2008, 2009, 2012; Williams et al., 2007, 2008a, 2008b; Williams and Lindquist, 2007; Williams and Masiunas, 2006) and one unpublished study (author, unpublished data). The objectives addressed issues of weed management, interspecific (crop–weed) competition, or intraspecific (crop–crop) competition in sweet corn. All studies measured fresh kernel mass, as well as other crop traits. Collectively, field experiments were conducted in 22 different growing environments over a period of 8 years. A total of 31 processing sweet corn hybrids were evaluated. Seventeen sweet corn plant, ear, and yield traits were identified, although not all traits were reported in every study (Table 1). The compiled dataset had up to 1080 observations of individual crop traits.

The methodological approaches used to grow the crop and characterize traits were largely consistent across studies. All experimental units (i.e. plots) were four 76-cm spaced rows of sweet corn ranging in length of 9.2–12.2 m. Thermal times from emergence or planting to mid-silk (R1 stage) and harvest (R3 stage) were characterized with cumulative growing degree days (GDD) using a base temperature of 10 °C and daily temperature data from a weather station within 1 km of experimental locations. Plant height was measured from the soil surface to the uppermost leaf or plant apex near silking. Also near the time of silking, plant leaf area index (LAI)

Table 1
Summary statistics of 17 sweet corn plant, ear, and yield traits and three crop response variables important to the sweet corn processing industry. Correlations between traits and processor variables are presented, whereby correlations in boldface type are significant at alpha = 0.05.[a]

Type	Trait	Units	CGS	Summary statistics				Processor variable		
								Recovery	Case production	Gross profit margin
				mean	sd	range	*n*	Correlation coefficient		
Plant trait	Thermal time to mid-silk	GDD	R1	729	59	566–950	709	**−0.170**	**−0.128**	**−0.128**
	Thermal time to harvest	GDD	R3	1011	70	898–1202	672	**0.395**	**0.247**	**0.263**
	Plant height	cm	R1	180	23	133–263	856	**−0.707**	**0.116**	**0.108**
	Plant LAI	$m^2\ m^{-2}$	R1	4.26	1.35	1.06–7.92	866	**0.236**	**0.491**	**0.484**
	Plant IPAR	%	R1	85.5	8.8	48.2–98.5	882	**0.093**	**0.374**	**0.361**
Ear trait	Ear number per plant	ears $plant^{-1}$	R3	0.78	0.23	0–1.56	903	**0.235**	**0.679**	**0.661**
	Ear length	cm	R3	19.6	1.6	11.8–24.0	864	0.051	**0.330**	**0.320**
	Filled ear length	cm	R3	17.9	1.9	7.0–23.5	864	**0.085**	**0.410**	**0.397**
	Percent filled length	%	R3	91.1	5.5	48.7–100.0	864	**0.112**	**0.328**	**0.318**
	Row number	–	R3	18.2	0.9	16.4–19.6	79	**0.244**	**0.374**	**0.375**
	Kernel number per row	–	R3	35.5	4.2	26.4–43.6	78	**−0.483**	−0.178	−0.195
	Ear width	mm	R3	41.8	2.0	37.5–47.0	79	**0.615**	**0.755**	**0.763**
	Kernel depth	mm	R3	7.3	1.3	4.9–9.4	79	**0.824**	**0.724**	**0.741**
Yield trait	Ear number	boxes ha^{-1}	R3	961	320	0–1830	1080	**0.394**	**0.869**	**0.854**
	Green ear mass	Mt ha^{-1}	R3	14.58	5.57	0–28.89	1079	**0.430**	**0.952**	**0.937**
	Husked ear mass	Mt ha^{-1}	R3	10.05	4.02	0–18.97	1080	**0.543**	**0.982**	**0.974**
	Fresh kernel mass	Mt ha^{-1}	R3	5.21	2.33	0–11.66	1075	**0.654**	**1.000**	**0.999**
Processor variable	Recovery	%	R3	35.0	5.3	1.5–58.1	1062	**1.000**	–	–
	Case production	cases ha^{-1}	R3	849	379	0–1902	1075	**0.654**	**1.000**	–
	Gross profit margin	\$ ha^{-1}	R3	8604	3969	−1322–20,329	1074	**0.682**	**0.999**	**1.000**

[a] Abbreviations: LAI, leaf area index; IPAR, intercepted photosynthetically active radiation; GDD, growing degree days; CGS, crop growth stage.