Kansas Agricultural Experiment Station Research Reports

Volume 8
Issue 4 *Kansas Field Research*

Article 3

2022

Corn Tiller Yield Contributions are Dependent on Environment: A 17 Site-Year Kansas Study

R. L. Veenstra
Kansas State University, rveenstra@ksu.edu

D. Berning
Corteva Agriscience, Johnston, IA

P. Carter
Formerly Corteva Agriscience, Independent Agronomist, Clive, IA

See next page for additional authors

Recommended Citation

Veenstra, R. L.; Berning, D.; Carter, P.; Wallace, S.; Legleiter, M.; Currie, L.; Messina, C. D.; Prasad, P. V. Vara; Hefley, T. J.; Haag, L. A.; and Ciampitti, I. A. (2022) "Corn Tiller Yield Contributions are Dependent on Environment: A 17 Site-Year Kansas Study," *Kansas Agricultural Experiment Station Research Reports*: Vol. 8: Iss. 4. https://doi.org/10.4148/2378-5977.8297

Corn Tiller Yield Contributions are Dependent on Environment: A 17 Site-Year Kansas Study

Authors

R. L. Veenstra, D. Berning, P. Carter, S. Wallace, M. Legleiter, L. Currie, C. D. Messina, P. V. Vara Prasad, T. J. Hefley, L. A. Haag, and I. A. Ciampitti

Corn Tiller Yield Contributions are Dependent on Environment: A 17 Site-Year Kansas Study

R.L. Veenstra, D. Berning,[1] P. Carter,[2] S. Wallace,[3] M. Legleiter,[4] L. Currie,[5] C.D. Messina,[6] P.V. Vara Prasad, T.J. Hefley, L.A. Haag, and I.A. Ciampitti

Summary

Historic breeding efforts in corn (*Zea mays* L.) have resulted in uniform, single-stalked phenotypes with limited potential for environmental plasticity. Therefore, plant density is a critical yield component for corn, as corn is unable to successfully compensate for a deficit of plants. Other grass crop species can overcome plant density deficits via vegetative branching (tillering), but this trait is historically undesirable in corn. Improving corn flexibility across plant densities has potential benefits, particularly considering diverse yield environments and seasonal weather uncertainties due to climate change. The present study evaluated tiller presence with two hybrids in a range of plant densities across the state of Kansas to identify yield impacts and potential usefulness of this plasticity trait in corn. Tiller presence was identified as neutral or additive to final yields, but fine-tuning plant density was confirmed as key to maximizing grain yields. Tillers have potential to stabilize yields across plant densities in productive environments. This capability may offer a source of production stability for growers when deficits develop in plant density after planting.

Introduction

Plant density is a management strategy to optimize the balance between crop needs and resource availability (Laitinen and Nikoloski, 2019). Specifically in corn (*Zea mays* L.), optimal plant density has historically increased as a key driver of modern yield gains (Duvick et al., 2004). Crop plasticity, the ability of a genotype to express alternative phenotypes and adapt to contrasting environmental scenarios, is marginal in corn compared to other cultivated crops. Due to this comparatively lower plasticity, corn yields are notably dependent on plant density. This attribute is less desirable in challenging or otherwise unpredictable growing conditions (Mylonas et al., 2020).

[1] Corteva Agriscience, Johnston, IA.

[2] Formerly Corteva Agriscience, Independent Agronomist, Clive, IA.

[3] Corteva Agriscience, Lubbock, TX.

[4] Corteva Agriscience, Wamego, KS.

[5] Corteva Agriscience, Garden City, KS.

[6] University of Florida, Gainesville, FL.

Corn adjusts its final grain production via yield components (namely ears per area, kernels per ear, and weight per kernel). The corn yield component most easily altered via management practices is ears per area, which is adapted with plant density and prolific (multi-eared) hybrid selection. Other Poacea species, such as wheat (*Triticum aestivum* L.) and grain sorghum (*Sorghum bicolor* L. Moench), increase the number of inflorescences per area by producing additional vegetative shoots (tillers). Although genetically different from its more grass-like ancestor (*Zea mays* ssp. *parviglumis*), corn remains capable of producing tillers. This trait is often suppressed in modern hybrids (Moulia et al., 1999). Corn tillers that do appear may remain vegetative, produce harvestable grain, or develop abnormal inflorescences without harvestable grain ("tassel ears"). Due to these unpredictable, undesirable outcomes, corn tillers have been historically associated with yield reductions. For this reason, corn tillers are commonly referred to as "suckers" (Jenkins, 1941).

Growers commonly voice concerns about tiller presence in corn fields, and conclusive evidence on tillering impacts (particularly in Kansas) is lacking. Therefore, this multi-season study sought to understand 1) the impact of tiller expression on yield in varying environments, and 2) the potential of tillers as a plasticity trait in Kansas environments.

Procedures

Data presented in this report were collected during a multi-year statewide study (2019-2021). Location characterizations are provided in Table 1.

Twelve site-years were established with a split-split-plot design, evaluating three factors: whole plot of planting density with three levels (10000, 17000, and 24000 plants/a), sub-plot of hybrid with two levels (P0805AM and P0657AM), and sub-sub-plot of tiller presence with two levels (removal at the V10 [tenth-leaf; Ritchie et al., 1997] development stage [TR], or intact throughout the season [TI]; Table 1). The remaining five site-years were established without the tiller presence factor (Table 1). In total, seventeen site-years were evaluated with at least three replications each.

Grain yields were harvested from the two central plot rows and adjusted to 15.5% standard grain moisture. Sites were clustered into three yield environments (low-, moderate-, and high-yielding; LYE, MYE, and HYE respectively) via a k-means algorithm. A linear mixed effects model was fit with grain yield as the response considering 1) fixed effects of treatment factors interacting with yield environment, and 2) random effects of site-year and design factors. The fitted model was subjected to a 3-way analysis of variance (ANOVA) and subsequent means comparison (Tukey method). A second linear mixed effects model was fit with grain yield as the response considering 1) fixed effects of observed plant density, observed tiller density, and interactions with yield environment; and 2) random effects of site-year and design factors. Predictions were generated with model coefficients based on the range of density observations across trials. All analyses and figures were generated with the R software (R Core Team, 2021).

Results

The ANOVA results for the treatment factor model are shown in Table 2. The interaction of yield environment with both plant density ($P \leq 0.001$) and tiller presence ($P \leq 0.01$) impacted final yields. Subsequent means comparisons are shown by yield environment in Figure 1. Plant density thresholds for grain yields within the evaluated ranges were 10,000 plants/a in the LYE, 17,000 plants/a in the MYE, and 24,000 plants/a in the HYE. Tiller presence did not reduce yields in any environment, instead tillers increased the overall yields in the HYE.

The ANOVA results for the observational analysis are shown in Table 2. The interaction of yield environment with both observed plant density and observed tiller density impacted yield predictions, in addition to the triple interaction of environment and observed densities (all significant at $P \leq 0.001$). Plotted predictions are shown by yield environment in Figure 2. Overall yields both with and without tillers were stable across observed plant densities in the LYE. Overall yields were more stable with greater tiller densities across observed plant densities in the MYE and HYE. Regardless of yield environment, greatest yields were realized when plant density was optimized, minimizing tiller expression.

The results of this study support the hypotheses that 1) tiller presence alone does not reduce corn yields across environments; and 2) tillers are an indication of plant density deficits but can be useful in stabilizing these deficits in productive environments. Additional information on this study can be found in Veenstra et al. (2021).

References

Duvick, D. N., Smith, J. S. C., & Cooper, M. (2004). Long-term selection in a commercial hybrid maize breeding program. In *Plant Breeding Reviews* (pp. 109–151). John Wiley & Sons, Inc. *https://doi.org/10.1002/9780470650288.ch4*.

Jenkins, M. T. (1941). Influence of climate and weather on growth of corn. In *Yearbook of Agriculture*. United States Department of Agriculture.

Laitinen, R. A. E., & Nikoloski, Z. (2019). Genetic basis of plasticity in plants. *Journal of Experimental Botany*, *70*(3), 739–745. *https://doi.org/10.1093/jxb/ery404*.

Moulia, B., Loup, C., Chartier, M., Allirand, J. M., & Edelin, C. (1999). Dynamics of architectural development of isolated plants of maize (*Zea mays* L.), in a non-limiting environment: The branching potential of modern maize. *Annals of Botany*, *84*(5), 645–656. *https://doi.org/10.1006/anbo.1999.0960*.

Mylonas, I., Sinapidou, E., Remountakis, E., Sistanis, I., Pankou, C., Ninou, E., Papadopoulos, I., Papathanasiou, F., Lithourgidis, A., Gekas, F., Dordas, C., Tzantarmas, C., Kargiotidou, A., Tokamani, M., Sandaltzopoulos, R., & Tokatlidis, I. S. (2020). Improved plant yield efficiency alleviates the erratic optimum density in maize. *Agronomy Journal*, *112*(3), 1690–1701. *https://doi.org/10.1002/agj2.20187*.

R Core Team. (2021). *R: a language and environment for statistical computing*. *https://www.r-project.org/*.

Ritchie, S. W., Hanway, J. J., & Benson, G. O. (1997). How a corn plant develops. *Iowa State University Coop. Ext. Serv.*, *48*.

Veenstra, R. L., Messina, C. D., Berning, D., Haag, L. A., Carter, P., Hefley, T. J., Prasad, P. V. V., & Ciampitti, I. A. (2021). Effect of tillers on corn yield: Exploring trait plasticity potential in unpredictable environments. *Crop Science*, *61*(5), 3660–3674. *https://doi.org/10.1002/csc2.20576*.

Table 1. Site-year characterizations

Site-year	Latitude	Longitude	Treatment structure	pH	OM	NO_3-N	NH_4-N	P	Soil texture
	°N	°W		H_20	% LOI	ppm	ppm	Mehlich, ppm	
Manhattan 19 $_L$	39.14	96.64	D × G × P	6.3	1.0	1.8	1.3	37.5	Sandy Loam
Garden City 19 $_M$	37.83	100.86	D† × G × P	6.6	1.0	2.0	0.0	42.0	Sandy Loam
Goodland 19 $_H$	39.25	101.78	D† × G × P	6.5	2.7	26.8	2.1	52.1	Silt Loam
Keats 20 $_H$	39.23	96.72	D × G × P	7.0	4.5	18.0	4.1	118.0	Silty Clay Loam
Buhler 20 $_M$	38.14	97.73	D × G	6.4	2.9	17.9	4.8	24.0	Silty Clay Loam
Greensburg 20 $_H$	37.58	99.37	D × G	5.4	2.6	37.1	13.6	84.9	Clay Loam
Garden City 20 $_H$	37.83	100.86	D × G × P	5.2	1.6	18.4	10.7	55.0	Sandy Loam
Goodland 20 $_H$	39.25	101.78	D × G × P	5.8	3.8	36.9	17.9	106.0	Silt Loam
Colby A 20 $_M$	39.39	101.06	D × G × P	5.4	3.3	19.9	4.3	70.0	Silt Loam
Colby B 20 $_L$	39.38	101.06	D × G × P	6.5	3.2	43.5	36.4	31.0	Silt Loam
Keats 21 $_H$	39.23	96.72	D × G × P	6.6	6.2	23.3	12.7	106.4	Silt Loam
Buhler 21 $_M$	38.14	97.73	D × G	6.3	2.6	11.7	7.8	13.3	Silt Loam
Greensburg 21 $_M$	37.58	99.37	D × G	5.6	2.3	33.4	7.4	68.8	Loam
Selkirk 21 $_H$	38.70	101.54	D × G	7.9	2.7	14.0	5.8	90.9	Loam
Garden City 21 $_M$	37.83	100.86	D × G × P	5.5	1.6	14.2	5.2	52.1	Sandy Loam
Goodland 21 $_H$	39.25	101.78	D × G × P	6.5	2.9	36.9	11.1	65.4	Loam
Colby A 21 $_L$	39.39	101.06	D × G × P	7.1	2.9	23.8	7.1	93.0	Clay Loam

Site-year identifiers with year (2019-2021) and yield environment (L-low, M-moderate, H-high); trial coordinates (°N and °W); treatment structure (D, plant density; G, genotype; P, tiller presence); and soil characterization [pH, organic matter (OM – loss on ignition (LOI)), nitrate concentration (NO_3-N), ammonium concentration (NH_4-N), phosphorus (P – Mehlich), and soil texture].
† Missing one level of designated treatment factor.

Table 2. Analysis of variance results for grain yield

Model	Source	df	Residual df	F value	*P*-value
Treatment factors	**Environment (E) × Plant density (D)**	**9**	**51.43**	**165.84**	***
	E × Genotype (G)	3	248.00	0.34	ns
	E × Tiller presence (P)	**3**	**186.00**	**4.92**	**
	E × D × G	6	248.00	1.35	ns
	E × D × P	6	186.00	1.96	ns
	E × G × P	3	186.00	1.68	ns
	E × D × G × P	6	186.00	0.71	ns
	Marginal R^2 = 0.80, Conditional R^2 = 0.88				
Field observations	**Environment (E) × Observed plant density (M)**	**3**	**56.32**	**132.09**	***
	E × Observed tiller density (T)	**3**	**351.09**	**22.35**	***
	E × M × T	**3**	**392.12**	**14.34**	***
	Marginal R^2 = 0.77, Conditional R^2 = 0.86				

Tested source of variation (Source), degrees of freedom (df), degrees of freedom of residuals (Residual df), F value, and the associated *p* value significance are presented. All sources with *P*-values ≤ 0.05 are shown in boldface font. Coefficient of determination values are provided.
*** Significant at P ≤ 0.001. ** Significant at P ≤ 0.01, ns not significant.

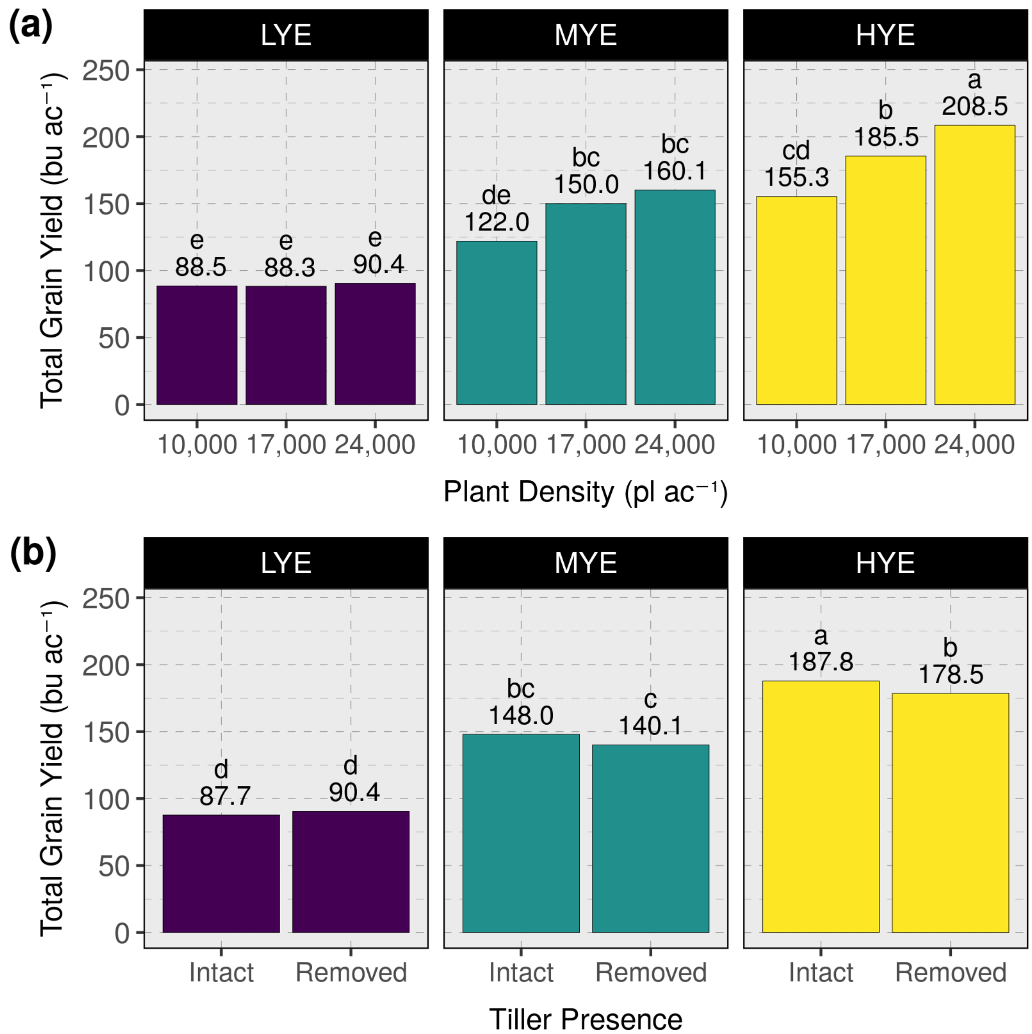

Figure 1. Mean yields and pairwise comparisons of treatment factors deemed significant in Table 2 (a, plant density; b, tiller presence) by yield environment (LYE, low-yielding environment; MYE, moderate-yielding environment; HYE, high-yielding environment). Means within a panel not sharing a common letter are significant at the 0.05 probability level.

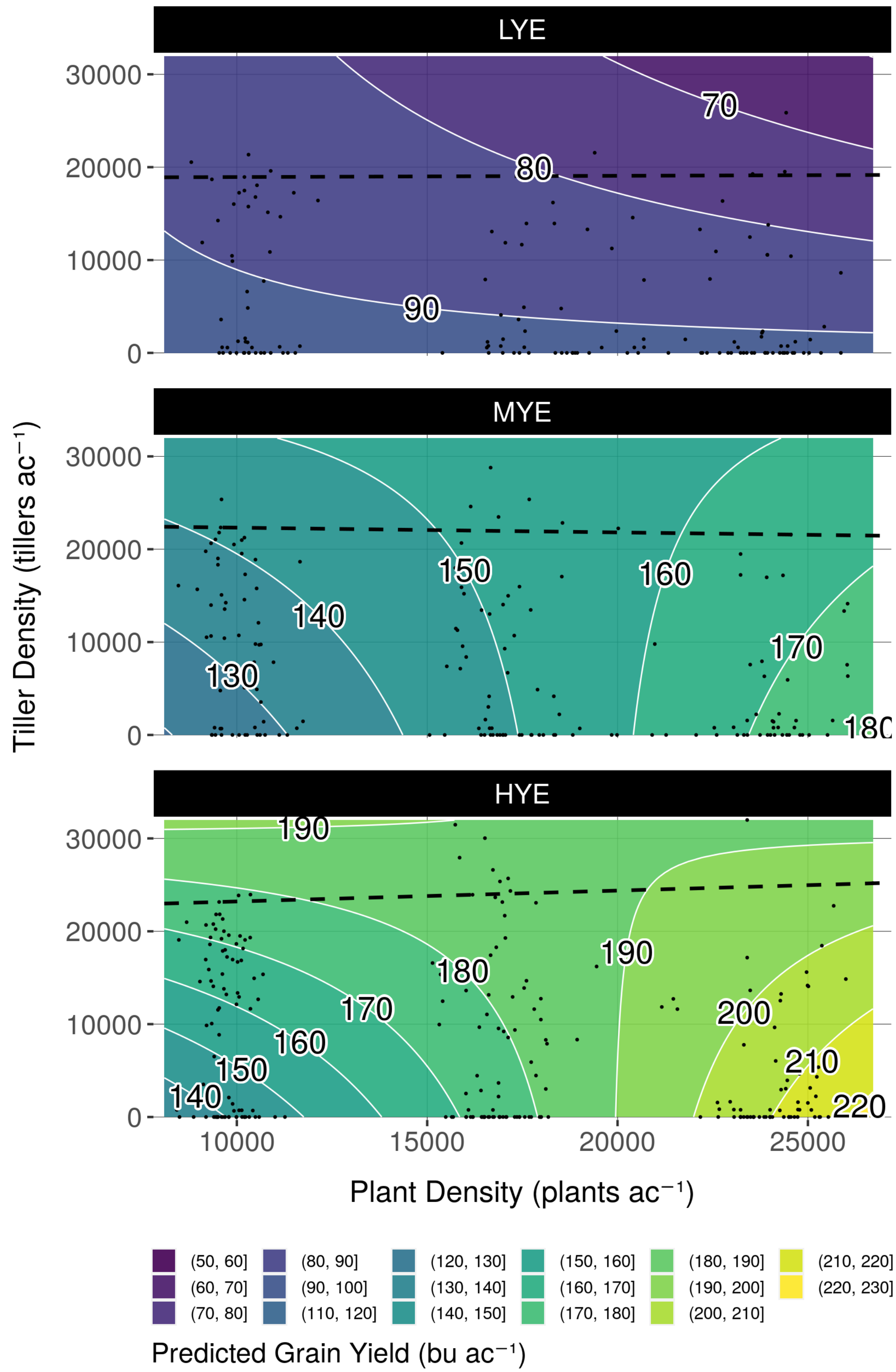

Figure 2. Observed density-based yield predictions by yield environment (LYE, Low-yielding environment; MYE, Moderate-yielding environment; HYE, High-yielding environment). Contours are shaded, delineated by white lines, and labeled according to 10 bu/a yield intervals. Observed plant densities and tiller densities are indicated with black points, and dashed regression lines consider the upper 95% of observed tiller densities by yield environment. Extrapolations beyond black points and dashed black lines are shown only for the purpose of comparing environments on the same density scales.