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Impact of Different Plant Canopy Traits on Sorghum Yields

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Summary

Studying changes in plant canopy can help to improve plant architecture and increase yields. Specifically, for sorghum (*Sorghum bicolor* L.), characterizing and identifying relevant canopy traits can be helpful not only to improve its productivity but to better fit this crop in the rotation from a system perspective. With this purpose, morphological characteristics of 20 sorghum hybrids were measured during the 2022 growing season in Wamego, KS, U.S. (United States). The most relevant canopy traits examined were leaf angle and leaf area at leaf- and at canopy-level (leaf area index, LAI), all determined at different points of the crop growth cycle (seventh-leaf, V7, flowering, and physiological maturity). Furthermore, duration of the vegetative and reproductive phases were also recorded as days to flowering, and days to maturity. A conditional decision tree analysis was employed to cluster the hybrids according to their variation in canopy characteristics and impact on yield. In summary, end of season LAI (at physiological maturity) was one of the most relevant plant canopy traits to group the hybrids and it accounted for ~70% of the variation. Hybrids with high LAI at V7 and low LAI at maturity, in addition to their longer time to maturity, presented greater yields. These findings can lead to future investigation using the same traits under different climatic conditions.

Introduction

Sorghum (*Sorghum bicolor L.*) is grown in the United States within the sorghum belt, a region which includes the states of Kansas, Texas, Colorado, Oklahoma, and South Dakota (Ciampitti and Prasad, 2020). The U.S. is one of the main world producers, with a proportion of 17% of the global sorghum production (FAOSTAT, 2022). Sorghum is known to be tolerant to water and heat stress, making it a suitable crop for overcoming adverse weather conditions. The canopy architecture plays a key role in explaining this tolerance (Kholová et al., 2013), and it was identified as one of the potential drivers of genetic gain (Demarco et al., 2022). Furthermore, changes in the canopy architecture had been employed to increase the number of plants per acre without yield penalties per plant, resulting in an increase of yield per acre (Duvick, 2005). However, even though sorghum presents great diversity in canopy architectures, to our knowledge no studies have explored the impact of these plant traits on U.S. commercial sorghum hybrids.

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Therefore, this study proposes to identify the importance of plant canopy traits associated with yield, via characterizing different canopy structures in a wide range of hybrids.

Procedures

Twenty hybrids were evaluated during the 2022 growing season at the Corteva Agriscience Station in Wamego, KS, U.S. The sorghum hybrids were planted on June 15 in a randomized complete block design, with three repetitions. Each plot consisted of eight rows with an interrow space of 30 in.

At the beginning of the season, 12 plants were selected per plot. The number of expanded leaves was recorded weekly. At three sampling moments (V7, flowering, and maturity) four plants were collected to measure leaf angle, and leaf area per leaf. Leaf area was measured per leaf, and then used to calculate the per unit area leaf area index (LAI).

The accumulated precipitation for the year was 33 in., and the mean temperature was 55°F (Figure 1). Precipitation for the year fell primarily (60% of the total) during May, June, and July, leading to low water availability late in the season.

The effect of canopy variation on yield was analyzed using analysis of variance (ANOVA). A conditional decision tree analysis was employed to group the hybrids according to the impact on yield of their canopy characteristics. All statistical analyses were performed with R software.

Results

The highest yield was achieved by the hybrid G6 (142 bu/a), while the lowest yield (66 bu/a) was attained by the hybrid G1 (Table 1). The hybrid G1 had a final number of leaves above the average (20 leaves) resulting also in greater LAI at both flowering and maturity. The hybrid with the highest yield presented a lower number of leaves (18 leaves) and lower LAI at both flowering and maturity when compared with the rest of the hybrids. The average time to flowering was 54 days across hybrids, ranging from 45 (hybrid G19) to 64 days (hybrid G2). Days to maturity presented an average across hybrids of 101 days but it ranged from 89 days (G19) to 111 days (G5). The hybrid G19 was the earliest for the group evaluated, with 45 days and 89 days to flowering and maturity, respectively. However, its yield was not the lowest among all hybrids (84 bu/a).

Results of ANOVA showed that yield was significantly influenced by LAI at maturity ($P \leq 0.05$). Furthermore, LAI at V7 and days to maturity showed a lower significance effect on grain yield ($P \leq 0.1$).

In accordance with these results, the percentages of variation explained by these traits were the highest among the explored traits (Figure 2). The leaf area index at maturity explained 36% of the yield variability, standing as the most relevant plant canopy trait. Other important traits to explain yield were LAI at V7 and days to maturity, explaining 16% and 15%, respectively. Traits such as leaf angle at maturity, leaf angle at V7, and leaf number at maturity explained a very minor proportion of the yield variation (Figure 2).

The conditional inference tree analysis grouped the hybrids according to the impact of tested plant canopy traits on yield. The most relevant trait to classify hybrids was LAI at maturity, separating hybrids with a LAI lower than 2.6, those sorghum materials resulting in greater yields. Days to maturity was the next relevant trait that divided the hybrids with lower LAI (Figure 3). Hybrids with durations greater than 93 days to maturity showed greater yields, highlighting the relevance of having a longer grain-filling period.

Conclusion

Leaf area index at maturity, LAI at V7, and days to maturity explained 70% of the yield variation and could be considered traits of interest in a breeding program. Hybrids with reduced LAI at maturity, also with greater LAI at V7, presented greater yields. These results might be dependent on the hybrids tested (canopy architecture) and characteristics of the climatic year (genotype × environment). Therefore, future studies should explore these traits in a broader range of environments.

Acknowledgments

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References

Ciampitti, I. A., & Prasad, P. V. (2020). Sorghum: State of the art and future perspectives. ISBN: 978-0-891-18627-4

Demarco, P. A., Mayor, L., Rotundo, J. L., Prasad, P. V., Morris, G. P., Fernandez, J. A., ... & Ciampitti, I. A. (2022). Retrospective study in US commercial sorghum breeding: II. Physiological changes associated to yield gain. *Crop Science*. *https://doi.org/10.1002/csc2.20845*

Duvick, D. N. (2005). The contribution of breeding to yield advances in maize (Zea mays L.). *Advances in Agronomy*, *86*, 83-145.

Food and Agricultural Organization of the United Nations (FAO). (2020). Crops and livestock products. Sorghum. 2019. FAO. *https://www.fao.org/faostat/en/#data/QCL/visualize*.

Kholová, J., Murugesan, T., Kaliamoorthy, S., Malayee, S., Baddam, R., Hammer, G. L., ... & Vadez, V. (2014). Modeling the effect of plant water use traits on yield and stay-green expression in sorghum. *Functional Plant Biology*, *41*(11), 1019-1034.

Rakshit, S., Hariprasanna, K., Gomashe, S., Ganapathy, K. N., Das, I. K., Ramana, O. V., ... & Patil, J. V. (2014). Changes in area, yield gains, and yield stability of sorghum in major sorghum-producing countries, 1970 to 2009. *Crop Science*, *54*(4), 1571-1584.

Table 1. Mean and standard deviation of the evaluated traits for the three phenological states across hybrids

	V7				Flowering						Maturity									
	Angle (°)		LAI		Angle (°)		LAI		DTF (days)		Angle (°)		LAI		DTM (days)		Leaf number		Yield (bu/a)	
Hybrid	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
G1	29	5	0.6	0.1	33	4	5	1	62	2	39	6	3	0.5	109	4	20	0.6	66	5
G2	34	6	0.7	0.2	39	4	5	0.2	64	6	38	3	3	0.8	110	2	21	0.6	82	9
G3	31	5	0.8	0	39	3	6	0.2	60	1	37	6	3	0.2	106	4	20	1	111	9
G4	35	4	0.5	0.2	38	4	4	0.9	64	6	43	4	3	1.1	108	6	22	0.6	69	23
G5	26	6	0.7	0.5	32	1	5	0.1	60	2	34	2	3	0.8	111	0	20	0.6	129	27
G6	34	1	0.6	0.1	32	2	4	0.5	56	0	38	9	2	0.2	109	4	18	0.6	142	13
G7	25	3	0.6	0	29	4	4	0.9	59	2	46	11	2	0.6	109	4	19	0	117	3
G8	33	5	0.6	0.1	28	3	4	0.5	56	1	32	2	2	0.2	106	4	18	0.6	110	14
G9	29	5	0.7	0.1	35	2	5	0.9	56	0	36	3	2	0.3	105	3	19	0.6	122	7
G10	28	1	0.5	0.1	31	4	4	1.6	56	0	36	1	2	0.1	108	4	20	1	118	6
G11	33	6	0.5	0.2	33	4	3	0.4	48	4	40	1	2	0.1	96	6	18	0.6	96	19
G12	26	1	0.6	0.2	26	1	4	0.6	56	0	25	2	3	0.4	105	3	19	0	114	14
G13	27	3	0.7	0.2	27	4	4	0.5	49	6	28	2	2	0.9	99	5	18	0.6	98	11
G14	26	3	0.5	0.2	24	4	3	0.2	46	1	30	2	2	0.1	90	1	20	3.8	109	10
G15	29	4	0.7	0.2	28	1	4	0.5	48	4	37	7	2	0.3	96	7	17	0	102	14
G16	25	1	0.7	0.2	30	5	4	0.4	55	2	33	6	3	0.1	98	4	19	1	110	16
G17	29	2	0.5	0.1	32	1	4	0.3	49	6	31	4	2	0.2	92	5	17	0.6	108	17
G18	23	5	0.5	0.2	28	2	3	0.2	46	0	31	5	2	0.2	92	4	17	1.5	95	10
G19	32	7	0.5	0.1	35	3	2	0.3	45	1	44	5	2	0	89	0	16	0.6	84	7
G20	36	4	0.7	0.4	40	4	2	0.3	46	0	43	5	2	0.2	90	1	16	1.2	95	1

Angle refers to the leaf angle insertion. LAI = leaf area index. DTF = days to flowering. DTM = days to maturity. Leaf number = the last leaf registered. SD = standard deviation.

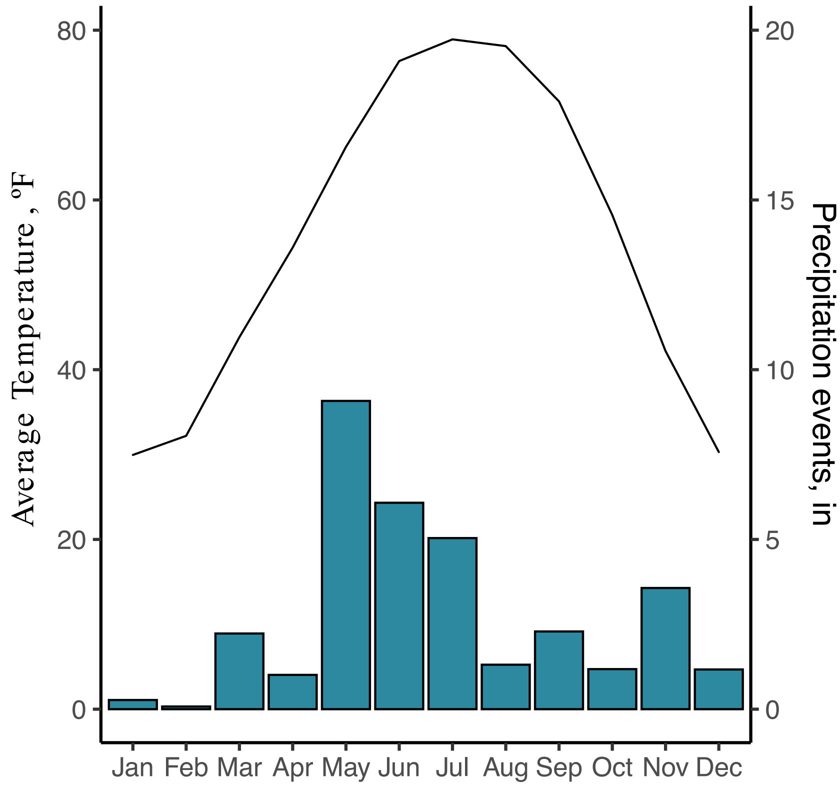

Figure 1. Monthly distribution of the daily average temperature and cumulative precipitation, across the 2022 year for Wamego, KS.

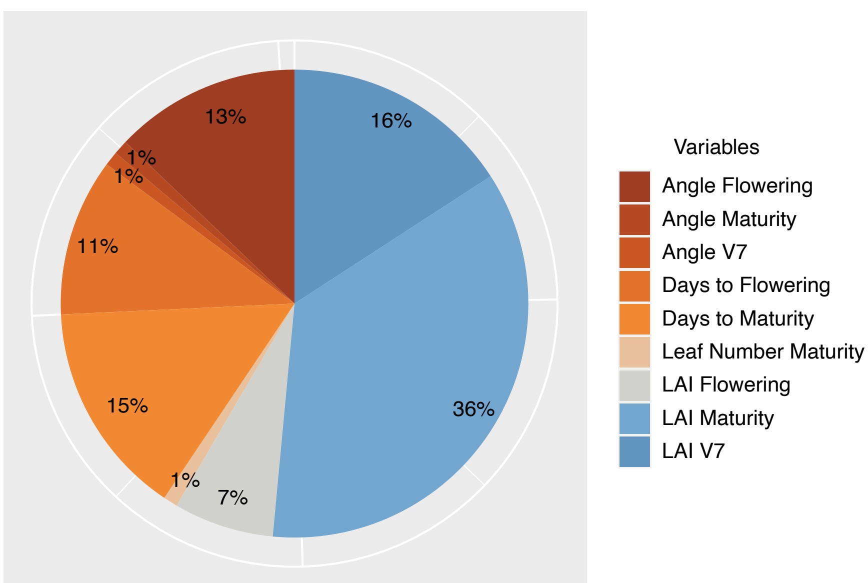

Figure 2. Distribution of the explained yield variance by the canopy architecture traits and phenology. These percentages were calculated based on the sum of squares obtained in the ANOVA analysis.

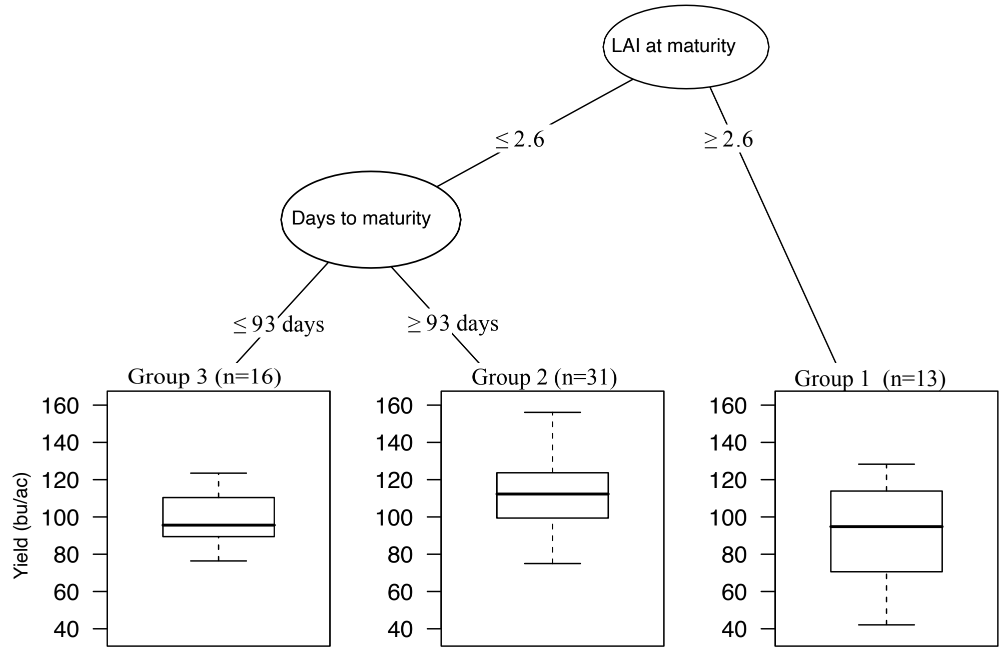

Figure 3. Conditional inference tree explaining the yield variation employing the canopy architecture and phenology traits. In each boxplot, the central rectangle spans the first to the third yield quartiles. The solid line inside the rectangle shows the mean. The upper and lower whiskers represent the maximum and minimum values.