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Short Communication

Canopy temperature in Sorghum under drought stress: Influence of gas-exchange parameters

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Drought resistance is often regarded as a complex trait, arising from different underlying constitutive or adaptive traits, each of which is potentially under complex genetic and environmental control. The assessment of leaf or canopy temperature (CT) has been proposed as a low-cost indirect selection criterion for drought and heat stress resistance Canopy temperature is indirectly related to stomatal conductance and carbon exchange (Anderegg *et al*., 2021). The photosynthesis gets affected by elevated leaf temperature in response to high ambient temperature only or in combination with drought due to reduced stomatal conductance (Pradhan *et al*., 2022). Under unfavourable soil-water conditions, greater CTD and yield have been attributed to increased stomatal conductance and crop water use (Balota *et al*., 2008). Hence, the present study was mainly focused on understanding the effects of drought stress on canopy temperature and to test the hypothesis that cooler canopy is more critical for better performance under drought stress in sorghum genotypes.

The experiment was conducted under the AICRP - Sorghum at the Regional Agricultural Research Station, Vijayapura. Eighteen genotypes were studied which varied with phenological characteristics in both irrigated and stressed conditions. The irrigated regime was provided with water periodically until the physiological maturity stage while drought stress was induced by withholding the irrigation post 40 days after emergence uniformly. The gas exchange parameters were determined with LI - 6800 portable closed chamber infrared gas analyser (LI-COR Biosciences, Lincoln, NE, USA). An infrared thermocouple was used to record the canopy temperatures. The infrared thermocouple was placed at one meter height from the top most leaf of that particular genotype. The data for each genotype were the mean of four readings (Jokar *et al.* 2018; Karimizadheh *et al*., 2011). The canopy temperature depression was obtained as a difference of the canopy temperature from the ambient air temperature. The analysis of variance (ANOVA) was done as suggested by Gomez and Gomez. The correlation and relationship studies were performed in the RStudio (B Corporation, Boston, MA) using “Corrplot”, “tidyverse” and “ggplot2” packages.

The difference in assimilation rate was 37%, transpiration rate was 32% and that of stomatal conductance was 36% between the irrigated and stressed regime. The best performance was recorded by Phule Anuradha and RSV 1876 under the stressed regime. They maintained photosynthetic rate at 16.30 μmol/m^2/s and 16.22 μmol/

m^2/s respectively as depicted in Table 1. The lines showing higher photosynthetic activity under the drought stress are considered to be drought tolerant (Getnet *et al*., 2015). In view of this conclusion, the genotypes RSV 1876 and Phule Anuradha in the current study can be considered as drought tolerant. A concurrent performance was observed with the transpiration rate and the stomatal conductance. Phule Anuradha and RSV 18 were able to maintain transpiration rate of 4.48 mmol/m^2/s and 4.1 mmol/m^2/s respectively while stomatal conductance stood at 0.144 mol/m^2/s and 0.138 mol/m^2/s, respectively (Fig. 1). Rajarajan *et al.* (2021) expressed that the higher yields of sorghum are associated with higher transpiration rate under the water stress. In accordance with this statement, it was observed in the current study that the genotypes RSV 1876, Phule Anuradha and other genotypes when subjected to stress having higher transpiration rate also achieved higher grain yield and biomass accumulation as observed from the Table 1. There was a decline in the stomatal conductance when the genotypes were subjected to drought stress similar to what was observed by Goche *et al.* (2020).

Ambient air temperature while recording the observations was 36.2°C. The lowest canopy temperature was maintained by CRS 99 (34°C) followed by RNTN-13-39 (34.1°C) in the irrigated regime, but in the stressed regime the lowest canopy temperature was recorded in the RSV 1876 (34.5 °C) followed by Phule Anuradha (34.6°C) as can be observed from the Table 1. The genotype depicting highest deviation from the ambient air temperature will be having the highest canopy temperature depression and *vice-versa.* In the stressed regime, genotype RSV 1876 had lowest canopy temperature that resulted in highest canopy temperature depression of 1.7°C followed by Phule Anuradha with 1.6°C depression (Table 1). Drought-susceptible genotypes would be impaired in growth, produce lower biomass and exhibit higher CT already at the beginning of the measurement period (Anderegg *et al*., 2021). Ndiso *et al.* (2016) reported lower canopy temperature in drought tolerant genotypes.

The higher yields of sorghum are associated with a higher transpiration rate under the water stress. Higher transpirational rate and lower stomatal conductance contribute in higher canopy temperature depression owing to lower canopy temperatures (Rajarajan *et al.,* 2021). The drought tolerant genotypes RSV 1876 and Phule Anuradha had tighter control over the stomata when compared with the drought susceptible counterpart. The drought-sensitive genotype was less effective than the drought-tolerant counterpart in controlling stomatal responses as indicated by the prolonged delay in the reduction of stomatal conductance or the rise in leaf surface temperature, parameters which reflect stomatal closure/opening (Goche *et al*., 2020). Canopy temperatures under stress were also negatively correlated across genotypes with absolute grain yields ($r = -0.67$, $P < 0.05$) under stress (Fig. 2). Absolute grain-yield under drought-stress was correlated with canopy temperatures (Blum *et al*., 1989). The plants with cooler canopies are better able to regulate stomatal conductance leading to cooler leaves (canopy) compared to ambient conditions (Ginkel *et al*., 2006). Cooler canopy temperature at heading and grain filling stages led to increase in yield for each condition. They observed that the 1°C change in the CTD altered the yield broadly by 150-270 Kg/ha. Selection of cooler canopy temperature under conditions of soil-water depletion could favor the development of lines with high yield potential (Kepekhov, 2022). Canopy temperature (CT) has been confirmed to be related to stomatal conductance and can be an indirect indicator of plant water uptake capability under drought (Mahmood, 2020).

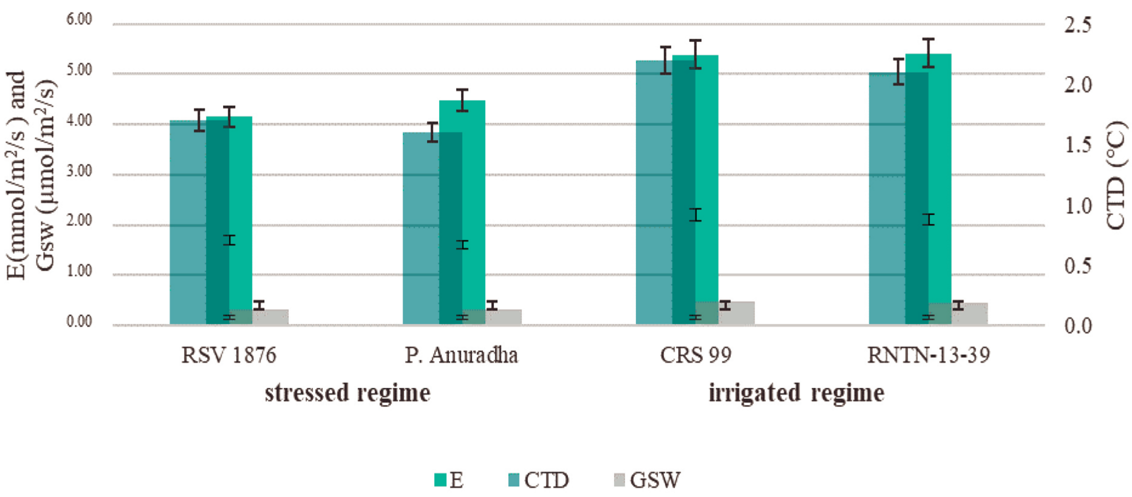

Fig 1: Canopy temperature in irrigated and stressed regime

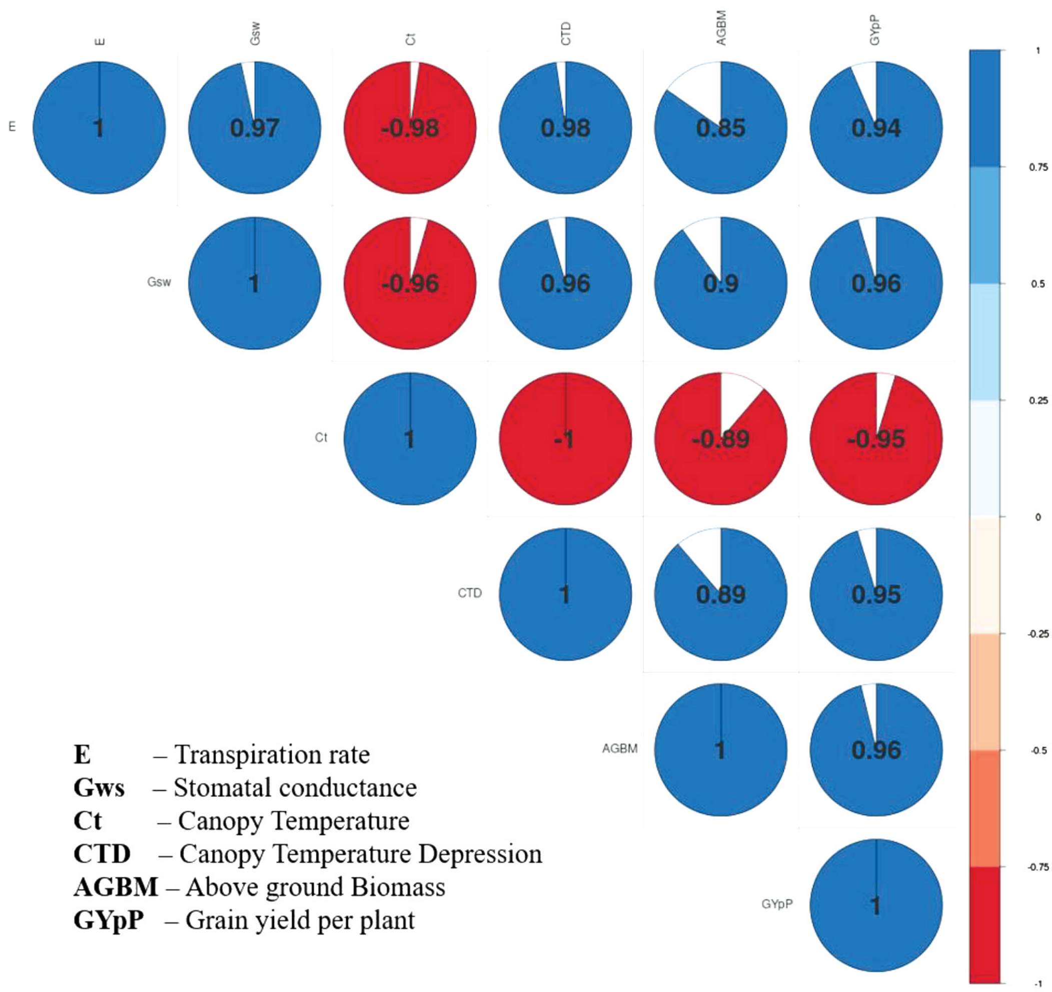

Fig 2: Correlogram of various attributes in sorghum genotypes

Table 1. Performance of genotypes under different moisture regimes as evaluated by various parameters

Genotype	Photosynthetic rate (µmol/m²/s)		Transpiration rate (mmol/m²/s)		Stomatal conductance (µmol/m²/s)		Canopy Temperature (°C)		Canopy temperature depression (°C)		Grain yield per plant (g)		Above ground biomass (g)	
	Irrigated	**Stressed**	**Irrigated**	**Stressed**	**Irrigated**	**Stressed**	**Irrigated**	**Stressed**	**Irrigated**	**Stressed**	**Irrigated**	**Stressed**	**Irrigated**	**Stressed**
RSV 1850	5.12	3.64	1.08	0.77	0.055	0.039	36.0	36.4	0.9	0.5	38.06	29.55	185.6	105.6
RSV 1876	19.64	17.27	4.22	3.71	0.155	0.136	35.1	35.2	1.8	1.7	60.09	53.65	228.9	202.5
RSV 1945	18.45	12.84	3.81	2.64	0.141	0.097	35.2	35.6	1.7	1.3	59.01	45.28	225.0	172.2
RSV 2371	16.76	11.60	3.30	2.28	0.126	0.087	35.3	35.6	1.6	1.3	57.75	44.18	224.5	170.4
CRS 89	14.24	8.88	3.05	1.90	0.122	0.076	35.4	35.7	1.5	1.2	56.17	40.83	221.1	155.4
CRS 93	12.87	8.24	2.96	1.89	0.114	0.072	35.5	35.8	1.4	1.1	54.50	40.10	218.2	151.4
CRS 95	12.61	8.64	2.76	1.89	0.111	0.075	35.5	35.7	1.4	1.2	54.05	41.11	216.5	153.8
CRS 98	12.05	5.82	2.68	1.28	0.108	0.051	35.5	36.0	1.4	0.9	53.66	35.40	216.1	141.4
CRS 99	26.88	13.33	5.40	2.67	0.205	0.101	34.7	35.6	2.2	1.3	65.25	43.38	242.2	174.3
VJP 2704	21.95	11.83	4.33	2.32	0.170	0.090	35.0	35.7	1.9	1.2	61.38	42.04	233.9	167.0
VJP 2705	13.99	10.24	3.16	2.31	0.116	0.084	35.4	35.6	1.5	1.3	55.58	43.86	220.7	165.2
RNTN-13-39	25.46	13.64	4.93	2.64	0.192	0.102	34.8	35.6	2.1	1.3	64.47	44.04	239.0	174.5
RNTN-14-1	14.36	6.49	2.80	1.26	0.113	0.050	35.4	36.1	1.5	0.8	55.73	36.03	220.6	140.6
RNTN-14-2	8.11	5.01	1.56	0.95	0.066	0.040	35.8	36.3	1.1	0.6	43.50	31.51	194.3	110.5
RNTN-14-3	8.41	6.69	1.79	1.42	0.075	0.060	35.8	36.0	1.1	0.9	44.75	37.16	195.6	129.6
M-35-1	14.00	8.97	2.76	1.76	0.109	0.069	35.4	35.7	1.5	1.2	55.60	40.93	218.6	152.1
P. Suchitra	18.10	10.44	3.72	2.15	0.142	0.081	35.2	35.7	1.7	1.2	58.69	41.24	227.0	160.3
P. Anuradha	21.86	17.65	4.65	3.76	0.173	0.139	35.0	35.3	1.9	1.6	62.12	52.09	234.3	201.1
Mean	15.82	10.07	3.28	2.09	0.127	0.080	35.3	35.8	1.6	1.2	55.57	41.24	220.1	157.1
	Sem(±)	CD @ 5%	Sem(±)	CD @ 5%	Sem	CD	Sem	CD	Sem	CD	S.Em	LSD @5%	S.Em	LSD @5%
Main plot	0.168	2.13	0.157	1.99	0.01	0.08	0.01	0.11	0.00	0.03	0.02	0.26	0.11	1.51
Sub plot	0.146	0.46	0.03	0.09	0.00	0.00	0.01	0.02	0.00	0.01	2.91	9.27	2.07	6.61

This study confirms the dependability of canopy temperature on the gas-exchange parameters in sorghum. The cooler canopy is essential for the regular metabolic activity on the plant which is more evident in the drought tolerant genotypes. The positive association of that with canopy temperature depression in a genotype is of profound importance. Another observation is that the canopy temperature is not an independent attribute but, it is dependent on the gas exchange parameters transpiration rate and stomatal conductance properties unique to that genotype.

Conflict of interest

The authors declare no conflict of interest

Consent for publication

All the authors provided consent and approved the submission of the manuscript to the journal of cereal research

Compliance with ethical standards:

NA

Authors contribution

All authors provided critical input and helped to shape the research, analysis and manuscript.

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