Letters to the Editor

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COMPARISON OF CANOPY TEMPERATURE BASED WATER STRESS INDICES IN WHEAT CROP

1. A field experiment was conducted on quantifying the cumulative values of six moisture stress indices in wheat, namely, canopy temperature ($T_c$), stress degree days (SDD), crop water stress index (CWSI), temperature stress day (TSD), canopy temperature variability (CTV) and satellite derived stress index (SDSI). It was observed that $T_c$, SDD and TSD stress indices were strongly related to water use by the crop and explained the crop yield variability in wheat. Therefore, under stress conditions, these indices can be exploited in understanding the water use by the crop and its influence on yield and yield contributing parameters.

2. Internal water status of the crop plants is a primary determinant of crop yields and is governed by the soil moisture availability, evaporative demand of the atmosphere and plant characteristics. Canopy temperature measurements show that they are related to internal water status of the plants and thus, could be used to detect whether the crop faces water stress or not (Ehrler et al. 1978).

Canopy temperature, as an index of crop moisture stress, is being used for screening drought tolerant varieties (Singh et al. 1985), for estimation of water stress in the plants and as an index of their response to water stress (Singh and Kanemasa 1983). A comparative analysis of six different stress indices have been made in the present paper to highlight the suitability of a particular index for crops in the region.

3. Material and methods—A field experiment was conducted during the rabi, 1986-87 using wheat (Triticum aestivum L.) var. WH-283 on the loamy soils at the research farm of Haryana Agricultural University, Hisar. The plots were 10.8 m x 6.0 m size. There were following four treatments of moisture stress levels created by differential irrigations:

(i) No post sowing irrigations ($T_1$)
(ii) One irrigation at flowering ($T_2$)
(iii) Two irrigations at CRI and jointing ($T_3$) and
(iv) Four irrigations at CRI, jointing, flowering and dough stages ($T_4$).

Pre-sowing irrigation was applied to all the treatments and all the recommended package of practices were followed. Each treatment was replicated four times. The crop was sown on 20 November 1986 with the help of manual seed drill and harvested at full maturity on 7 April 1987.

Soil moisture data were recorded at 15 days interval from sowing to harvesting by gravimetric method. Crop canopy temperatures and their differences with the ambient air temperature were recorded daily between 1300 and 1400 IST from 40 days after sowing up to maturity with the help of infrared thermometer (Tele-temp. AG-42 Model). At the same time dry and wet bulb temperatures were also measured with the help of Assmann psychrometer at a height of about 60 cm above the crop height.

The following six stress indices, based on crop canopy temperature, were computed in the analysis:

(i) Canopy temperature ($T_c$) [Tanner 1963]
(ii) Stress Degree Day (SDD) — Difference of canopy temperature with the ambient air temperature ($T_c - T_a$) (Idso et al. 1977, Jackson et al. 1977)
(iii) Crop water stress index (CWSI) — The method suggested by Idso et al. (1981) was used for computations of daily values of CWSI
(iv) Temperature stress day (TSD) as relative warming of stressed plots over the least stressed ($T_1$) [Gardener et al. 1981]
(v) Canopy temperature variability (CTV) — The daily range of canopy temperature within the same treatment was taken as CTV as suggested by Clawson and Blad (1982) and Gardener et al. (1981).
(vi) Satellite derived stress index (SDSI) — This index was suggested by Boatwright and Whitehead (1986) as follows:

$$SDSI = \frac{D_T - T_c}{N_T},$$

where, $D_T$ is satellite acquired day time maximum temperature,
$A_T$ is meteorological station day time temperature,
$N_T$ is the satellite acquired night time minimum temperature.

Due to non-availability of the satellite observations this index was computed with the use of ground data as follows:

$$SDSI = \frac{D_T - A_T}{D_T - N_T}.$$
where, \( D_T \) is taken as daily maximum temperature, 
\( N_T \) is daily minimum temperature.
\( A_T \) is daily canopy temperature between 1300 and 1400 IST.

The total water used by the crop was computed from soil moisture data using gravimetric method. The meteorological data of observatory (situated about 100 m from the experimental site) were also used whenever required for computing these indices.

4.1 Stress indices and water use

It was observed that there exists linear relationship between the stress indices (accumulated from 40 DAS to maturity) and the crop water use as below:

\[ \Delta T = 2460.31 - 0.72 \text{ WU} \quad (R^2 = 0.91) \]
\[ \text{DSDD} = 136.68 - 0.999 \text{ WU} \quad (R^2 = 0.88) \]
\[ \Delta \text{TSD} = 317.46 - 0.78 \text{ WU} \quad (R^2 = 0.89) \]
\[ \Delta \text{CWSI} = 58.76 - 0.112 \text{ WU} \quad (R^2 = 0.83) \]
\[ \Delta \text{CTV} = 11.79 - 0.99 \text{ WU} \quad (R^2 = 0.53) \]
\[ \text{SDSI} = 0.16 - 0.016 \text{ WU} \quad (R^2 = 0.70) \]

where, WU is the total water used by the crop during its growing season in mm. Sixteen observations were used for calculation of the regression equations.

It shows that canopy temperature is best related to water use, closely followed by TSD and SDD showing that these indices can be used as indicators of plant moisture regime. CTV performed the worst followed by SDSI whereas CWSI did fairly well.

Similar relationships between water use and these stress indices have been reported by Khara and Sandhu (1986) and Saha et al. (1986).

4.2 Stress indices and crop yields

Final grain yields were found to have very strong linear relationship with accumulation of canopy temperature derived stress indices. The linear regressions were of the following form:

\[ Y = 200.79 - 0.076 \Delta T \quad (R^2 = 0.82) \]
\[ Y = 213.35 - 0.054 \Delta \text{DSDD} \quad (R^2 = 0.80) \]
\[ Y = 41.14 - 0.44 \Delta \text{CWSI} \quad (R^2 = 0.73) \]
\[ Y = 35.81 - 0.069 \Delta \text{TSD} \quad (R^2 = 0.80) \]
\[ Y = 53.08 - 0.29 \Delta \text{CTV} \quad (R^2 = 0.38) \]
\[ Y = 17.20 - 2.58 \Delta \text{SDSI} \quad (R^2 = 0.58) \]

where, \( Y \) is grain yield in q/ha.

The cumulative values of \( T \), SDD and TSD had very strong relationships with the grain yields followed by CWSI which also did fairly well CTV was found to be the least related to the grain yields.

The relationship between the stress indices and yield can be explained on the grounds that canopy temperature increases due to reduced transpirational cooling caused by stomatal closure which hinders CO2 exchange and CO2 assimilation and, thus, affects the crop yields.

These results are in conformity with those reported by Idso et al. (1981b), Steiner et al. (1983) and Siva Kumar (1986).

References


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