Mausam, (1990), 41, 1, 131-144

Letters to the Editor

551.579.5 : 633.1

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 Kanemasu 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, Hissar. The plots were 10.8 m $\times$ 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 (Teletemp. 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 moisture 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.* (1981a) 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_4) [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 White head (1986) as follows :

$$\text{SDSI} = \frac{D_T - A_T}{D_T - N_T}$$

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 :

$$\text{SDSI} = \frac{D_T - A_T}{D_T - N_T},$$

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 :

$$\Sigma T_c = 2460.31 - 0.72 \text{ WU} \quad (R^2 = 0.91)$$
$$\Sigma \text{SDD} = 136.68 - 0.999 \text{ WU} \quad (R^2 = 0.88)$$
$$\Sigma \text{TSD} = 317.46 - 0.78 \text{ WU} \quad (R^2 = 0.89)$$
$$\Sigma \text{CWSI} = 58.76 - 0.112 \text{ WU} \quad (R^2 = 0.83)$$
$$\Sigma \text{CTV} = 11.79 - 0.99 \text{ WU} \quad (R^2 = 0.53)$$
$$\Sigma \text{SDSI} = 0.16 + 0.016 \text{ WU} \quad (R^2 = 0.70)$$

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 Khera 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 :

$$Y = 200.79 - 0.076 \ \Sigma T_c \quad (R^2 = 0.82)$$
$$Y = 21.35 - 0.054 \ \Sigma \text{SDD} \quad (R^2 = 0.80)$$
$$Y = 41.14 - 0.44 \ \Sigma \text{CWSI} \quad (R^2 = 0.73)$$
$$Y = 35.81 - 0.069 \ \Sigma \text{TSD} \quad (R^2 = 0.80)$$
$$Y = 53.08 - 0.29 \ \Sigma \text{CTV} \quad (R^2 = 0.38)$$
$$Y = 17.20 + 2.58 \ \Sigma \text{SDSI} \quad (R^2 = 0.58)$$

where, Y is grain yield in q/ha.

The cumulative values of T_c, 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 CO_2 exchange and CO_2 assimilation and, thus, affects the crop yields.

These results are in conformity with those reported by Idso *et al.* (1981b), Steiner *et al.* (1985) and Siva Kumar (1986).

References

Boatwright, G.O. and Whitehead, V.S., 1986, Early warning and crop condition assessment research, *IEEE Trans. Geosci. Remote Sens.*, **GE-24**, 54-63.

Clawson, K.L. and Blad, B.L., 1982, Infrared thermometry for scheduling irrigation of corn, *Agron. J.*, **74**, 311-316.

Ehrler, W.L., Idso, S.B., Jackson, R.D. and Reginato, R.J., 1978, Wheat canopy temperature : Relation to plant water potential, *Agron. J.*, **70**, 251-256.

Gardener, B.L., Blad, B.L. and Watts, D.G., 1981, Plant and air temperature in differentially irrigated corn., *Agric. Met.*, **25**, 207-217.

Idso, S.B., Jackson, R.D. and Reginato, R.J., 1977, Remote sensing of crop yields, *Science*, **196**, 19-25.

Idso, S.B., Reginato, R.J., Jackson, R.D. and Pinter, P.J. (Jr.), 1981 (a), Foliage and air temperature: Evidence for dynamic "Equivalent point", *Agric. Met.*, **24**, 223-226.

Idso, S.B., Reginato, R.J., Jackson, R.D. and Pinter, P.J. (Jr), 1981 (b), Measuring yield reducing plant water potential depressions in wheat by infrared thermometry, *Irri. Sci.*, **2**, 205-212.

Jackson, R.D., Reginato, R.J. and Idso, S.B., 1977, Wheat canopy temperature : A practical tool for evaluating water requirements, *Water Resour. Res.*, **13**, 651-656.

Khera, K.L. and Sandhu, B.S., 1986, Canopy temperature of sugar cane as influenced by irrigation regime, *Agric. For. Met.*, **37**, 245-258.

Saha, S.K., Ajai, Gopalan, A.K.S. and Kamat, D.S., 1986, Relations between remotely sensed canopy temperature, crop water stress, air vapour pressure deficit and evapotranspiration in chick pea, *Agric. For. Met.*, **38**, 17-26.

Singh, D.P., Singh, P., Kumar, A. and Sharma, H.C., 1985, Transpirational cooling as a screening technique for drought tolerance in oil seed Brassicas, *Ann. Bot.*, **58**, 815-820.

Singh, P. and Kanemasu, E.T., 1983, Leaf canopy temperatures of pearlmillet genotypes under irrigated and non-irrigated conditions, *Agron. J.*, **75**, 497-501.

Siva Kumar, M.V.K., 1986, Canopy-air temperature differentials, water use and yield of chick pea in a semi-arid environment, *Irri. Sci.*, **7**, 149-153.

Steiner, J.L., Smith, R.C.G., Meyer, W.S. and Adeney, J.A., 1985, Water use, foliage temperature and yield of irrigated wheat in southeast Australia, *Aust. J. agric. Res.*, 36, 1-11.

Tanner, C.B., 1963, Plant temperatures, *Agron. J.*, **55**, 210-211.

SUBHASH CHANDRA BHAN
O. P. BISHNOI
V. U. M. RAO

Haryana Agric. University,
Hissar

20 March 1989