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Development of crop water stress index of wheat crop for scheduling irrigation using infrared thermometry

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ABSTRACT

This study was conducted to develop the relationship between canopy–air temperature difference and vapour pressure deficit for no stress condition of wheat crop (baseline equations), which was used to quantify crop water stress index (CWSI) to schedule irrigation in winter wheat crop (*Triticum aestivum* L.). The randomized block design (RBD) was used to design the experimental layout with five levels of irrigation treatments based on the percentage depletion of available soil water (ASW) in the root zone. The maximum allowable depletion (MAD) of the available soil water (ASW) of 10, 40 and 60 per cent, fully wetted (no stress) and no irrigation (fully stressed) were maintained in the crop experiments. The lower (non-stressed) and upper (fully stressed) baselines were determined empirically from the canopy and ambient air temperature data obtained using infrared thermometry and vapour pressure deficit (VPD) under fully watered and maximum water stress crop, respectively. The canopy–air temperature difference and VPD resulted linear relationships and the slope (m) and intercept (c) for lower baseline of pre-heading and post-heading stages of wheat crop were found $m = -1.7466$, $c = -1.2646$ and $m = -1.1141$, $c = -2.0827$, respectively. The CWSI was determined by using the developed empirical equations for three irrigation schedules of different MAD of ASW. The established CWSI values can be used for monitoring plant water status and planning irrigation scheduling for wheat crop.

1. Introduction

The globally growing demand for water has ushered the need for its efficient and judicial utilizations in all fields, and agriculture in particular being a single largest consumer of water. The majority of irrigation projects in India perform at a very low efficiency, which calls for application of efficient water management technologies for meeting the increasing water demands. Estimation of soil moisture or crop evapotranspiration from climatic parameters provides objective criteria for irrigation management. Methods to estimate evapotranspiration require huge climatic data, which are seldom available and not applied by common crop growers. Estimation of crop water requirement through soil moisture requires soil moisture measurement at several locations, which is time consuming exercise and may not give proper assessment of crop water need. However, the plant based indicator approach considers the plant water status for scheduling irrigation. This might be considered as the ideal criterion because the plant water is a good integrator of the soil, water and climatic parameters.

When plants are under water stress causes stomatal closure, which interrupt in energy dissipation and result in rise of leaf temperature. The leaf or canopy temperature is used as an indicator of plant water stress (Jackson et al., 1981; Jackson, 1982). Idso et al. (1981) used non-water-stressed

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baselines established from relationship of canopy–air temperature difference of a well-watered crop and vapour pressure deficit (VPD) for estimating crop water stress index (CWSI). A wide range of empirical studies (Idso, 1982; Idso et al., 1990; Alves and Pereira, 2000) indicated that there may be different non-water-stressed baselines for different crops and these need to be determined for each agroclimatic zone. Kirda (2000) showed the water stress tolerance of crop at different growth stages under deficit irrigation scheduling. Orta et al. (2004) conducted a study in Turkey to develop baseline equations, which can be used to quantify crop water stress index (CWSI) for evaluating crop water stress in three winter wheat genotypes and to schedule irrigation and to predict yield. Luquet et al. (2004) assessed the limitations of water stress indices using directional thermal infrared (TIR) measurements and 3D simulations. Mahan et al. (2005) determined the temperature and time thresholds for BIOTIC irrigation of peanut. The foregoing discussion reveals that the application of canopy–air temperature difference based approach is appropriate for crop water stress determination as it is a nondestructive, non-contact, reliable, provides considerably precise estimation and represents actual crop water demand. Therefore, present study has been undertaken to establish crop water stresses of wheat grown in sub-humid subtropical region for irrigation scheduling using infrared thermometry.

2. Materials and methods

2.1. Study area

The study was conducted at the Experimental Farm of Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, India located at latitude of 22°18.5′N and 87°19′E longitude at an altitude of 48 m above mean sea level. The climate of study area is sub-humid subtropical with an average annual rainfall of 1390 mm. About 85% of rainfall occurs during June to September (rainy season), which has uneven distribution. The remaining amount of rainfall occurs mostly in summer season with very scanty to no rains in winter season. The soil of the experimental site is lateritic with sandy loam texture, shallow, acidic in nature, very poor in organic matter and low plant nutrient. The water holding capacity of soil is low with high infiltration rate.

2.2. Experimental layout

Field plot experiments were conducted for establishing the crop water stress index of wheat crop (*Triticum aestivum* L.) cv. Sonalika grown in winter season in the region. The experiments were conducted for two consecutive winter seasons 2003–2004 and 2004–2005. Wheat is usually a 110–115 days cereal crop grown in this region and suits the prevailing climate in the winter season (December to March).

The experimental area consists of 15 plots 5 m × 4 m size with a buffer of 1 m between adjacent plots. The randomized block design (RBD) was used for the experimental layout with treatments as the factor. There were five levels of irrigation treatments with three replications. The layout of the experiment is shown in Fig. 1.

2.3. Irrigation scheduling

Irrigation scheduling for wheat crop was done on the basis of percentage depletion of available soil water (ASW) in the root zone. The maximum allowable depletion (MAD) of ASW of 10, 40 and 60% was applied in the I_1, I_2 and I_3 treatments, respectively. Where as the treatment I_4 had no water stress, fully wetted with frequent supplies to maintain the soil moisture near field capacity. In the treatment I_5, no irrigation was given however; water was applied only for survival of crop once during the whole crop season (alternately in three replications to maintain extreme dry condition at least in one replication). The treatments I_1, I_2 and I_3 were selected for determining the optimum MAD level of ASW for irrigating

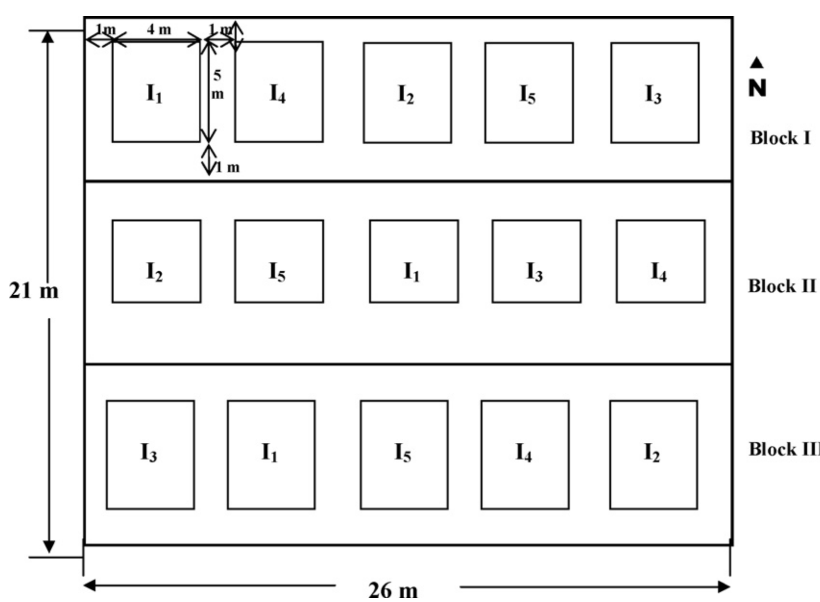

Fig. 1 – Experimental field layout of wheat crop.