

SUSCEPTIBILITY OF WHEAT TO WATER DEFICIT AT THREE GROWTH STAGES

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Abstract

The grain yield of wheat (*Triticum aestivum* L.) to different water deficit levels at three stages of growth was obtained from field measurements conducted at the Ahmadu Bello University Farm, Samaru-Zaria. Also, the suitability of a time-based characterisation of water deficit for crop susceptibility determination was tested against a plant-based one. The plant-based measure of crop water stress, as caused by water deficit, was calculated as the product of relative evapotranspiration deficit and the duration. The crop susceptibility was the relative grain yield reduction due to a given crop water stress.

The results showed that the level of water deficit determines the relative crop susceptibilities to water stress for the crop growth stages considered. Also, the relationship between time intervals (irrigation frequency as a measure of water deficit) and a plant-based water deficit varied during the crop growth season. Thus, the sole use of a time-based characterisation of water deficit for the determination of crop susceptibilities at defined growth stages is found to be unsuitable. However, since the local farmers may find it difficult to use the more sophisticated plant-based water deficit characterisation, a relationship between the plant-based and time-based water deficit characterisation for the different crop growth stages was established. Therefore, the plant-based water deficit characterisation can easily be estimated using the established relationship and the appropriate irrigation scheduling determined.

1. Introduction

It is generally accepted that crops subjected to water stress give reduced yields. The influence of moisture stress on grain yield is complex and depends on the duration, intensity, frequency and timing of the stress, genotype and environmental factors, such as nitrogen (Nix and Fitzpatrick, 1969). Generally, seed yields of determinate crops such as wheat are least sensitive to mild stress in the vegetative period, and stress sensitivity also diminishes in the later part of the grain filling period. Thus, it is necessary to provide enough water during the period of flowering to grain filling stage to ensure good grain yield.

Maurya (1980) reported the increasing incidence of waterlogging in irrigation projects in Nigeria due to excessive water application. This has resulted in soil salinity build-up as well. There is need, therefore, to develop practical water application methods that would ensure optimum use of water in irrigated agriculture. An improved irrigation scheduling technique which enables one to apply the required quantity of water at the appropriate time, called the Stress-Day Index (*SDI*) technique has been developed by Hiler (1969). This provides a quantitative means of determining the crop water stress imposed on a crop during its growing period which is then used as a criterion for characterising the need for irrigation. The *SDI*, defined as the actual crop water stress that is responsible for the reduction of the potential yield of the crop, is determined from two components, namely; the Stress-Day (*SD*) factor, and the Crop Susceptibility to water stress (*CS*) factor. The *SD* factor is a measure of the degree and duration of plant water stress, while the *CS* factor indicates the crop sensitivity to a given *SD*. Stegman *et al.* (1980) attributed the differing magnitudes of *CS* to differing definitions of growth stage length and methods of *SD* characterisations and/or differing levels of *SD*. This therefore, calls for the definition of *CS* not only to be as functions of crop species and growth stage, but also to be as functions of level of plant water deficits. Besides, since

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most Nigerian farmers are uneducated to adopt the more sophisticated *SD* characterisation, it would be important to develop simple characterisation that would be practical to the local farmer and also yield optimum results given our local situation. Thus, the objectives of this study were:

- (1) to determine the *CS* at different levels of water deficit at three growth stages of wheat crop; and
- (2) to develop a relationship between time-based and plant-based characterisation factors.

2. Materials and methods

The experiment was conducted at the Ahmadu Bello University Farm, Samaru, Zaria (11° 11'N; 7° 35'E). Following the local practice of a 7-day irrigation interval for wheat termed "standard practice", the control treatment was irrigated at 7-day intervals throughout the growing season.

Irrigation Treatments

The irrigation treatments used for the study are related to the three growth stages of wheat crop given in Table 1.

Table 1: Growth stages of wheat

Growth Stage	Description	Period (days after planting)
I	Stem elongation to booting	31-55
II	Ear emergence to flowering	56-69
III	Milk-dough development	70-83

Twelve stressed treatments were obtained by imposing four levels of a time-based quantification of water deficit, namely 3,7,10 and 14 days above the control, once at each of the three growth stages used. The details of the treatments used in the study are given in Table 2.

Table 2: Experimental treatments (irrigation was delayed once in all treatments)

Treatment	Description
C	Regular 7-day irrigation interval
AI	Irrigation delayed by 3 days, at stage I
AII	Irrigation delayed by 3 days, at stage II
AIII	Irrigation delayed by 3 days, at stage III
BI	Irrigation delayed by 7 days, at stage I
BII	Irrigation delayed by 7 days, at stage II
BIII	Irrigation delayed by 7 days, at stage III
CI	Irrigation delayed by 10 days, at stage I
CII	Irrigation delayed by 10 days, at stage II
CIII	Irrigation delayed by 10 days, at stage III
DI	Irrigation delayed by 14 days, at stage I
DII	Irrigation delayed by 14 days, at stage II
DIII	Irrigation delayed by 14 days, at stage III

The Stress-Day (SD) Factor

The SD factor at any particular time during the crop growth indicates how dry the crop is. Various methods of characterising the SD factor exist. In this study, SD characterisation involving the ratio of evapotranspiration to environmental evaporative demand (Equation 1) was used (Hiler and Clark, 1971).

$$SD = 1 - ET_d/ET_p \quad (1)$$

ET_a and ET_p are the actual and potential evapotranspiration amounts respectively, summed over a specified time period. In order to combine the degree and duration of crop water stress, Equation 1 requires daily determination of evapotranspiration amounts. Since this was however determined only once during each stress period, the plant-based SD were calculated as follows (Mogensen, 1980):

$$SD_p = (1 - ET_s/ET_p)N \quad (2)$$

in which ET_s and ET_p are the average evapotranspiration amounts from the stressed and control treatments respectively during N days of crop water stress. The evapotranspiration amounts were obtained using the water balance method based on the change in soil water storage determined at 150-mm intervals for a 600-mm root zone depth.

The Crop Susceptibility (CS) Factor

The crop susceptibility (CS) factor gives the relative reduction in crop yield by a given crop water deficit. The CS factor for a growth stage was determined experimentally as the fractional reduction in yield resulting from a predetermined critical water deficit occurring during the growth stage as given by Equation 3 (Hiler and Clark, 1971; Hiler *et al.*, 1974);

$$CS_i = (X - X_i)/X \quad (3)$$

Where;

CS_i = crop susceptibility factor for growth stage i ,
 X = marketable crop yield from a non-stressed treatment, and
 X_i = marketable yield from a treatment that was subjected to a water deficit at the i^{th} , growth stage.

Crop Yield

The grain yield was obtained for each plot by harvesting and threshing the crop in each plot manually and then weighing with the aid of an electronic balance. Considering the definition of the CS factor, only the dry grain yield was of interest, rather than the dry matter yield. Thus, the rate of crop growth was not monitored.

3. Results and discussion

Degree and Duration of Crop Water Stress

The computed values of the plant-based Stressed-Day (*SD*) factor as defined in Equation 2, corresponding to a specified number of days in excess of the local "standard practice" of a 7-day irrigation interval are given in Table 3.

Table 3: Measured evapotranspiration during stress periods with corresponding time-based and plant-based stress days

Treatment	Stress period (days since seeding)	ET _s (mm)	ET _c (mm)	SD _T (days)	SD _p (days)
AI	43-45	9.3	14.0	3	1.01
BI	43-49	23.5	32.7	7	1.97
CI	43-52	27.2	49.3	10	4.48
DI	43-56	36.1	71.4	14	6.92
AII	57-59	6.8	21.0	3	2.03
BII	57-63	13.4	49.0	7	5.09
CII	57-66	24.8	72.3	10	6.57
DII	57-70	25.7	103.4	14	10.52
AIII	71-73	1.4	19.3	3	2.78
BIII	71-77	3.6	45.0	7	6.44
CIII	71-80	10.3	61.9	10	8.34
DIII	71-84	27.6	84.4	14	10.18

ET_s Measured evapotranspiration from the stressed treatment during stress periods.

ET_c Evapotranspiration from the control treatment during stress periods.

SD_T Time-Based Stress Days.

SD_p Plant-Based Stress Days.

It can be observed that there are differences in the level and duration of stress imposed, as characterized by the *SD*, for the same time intervals at the defined growth stages. This can be attributed to the changes in the consumptive use and the evapotranspirative demands at the different stages of growth of the crop. Since *CS* depends on the level of the imposed crop water stress (Hiler et.al., 1974; Stegman *et al.*, 1980), it would be erroneous to define *CS* for defined crop growth stages solely on the bases of fixed-time intervals. Figure 1 gives the relationship between the plant-based *SD* and the time-based one, for the three growth stages. Thus, the number of days corresponding to defined plant-based *SD* levels can be determined at any growth stage.

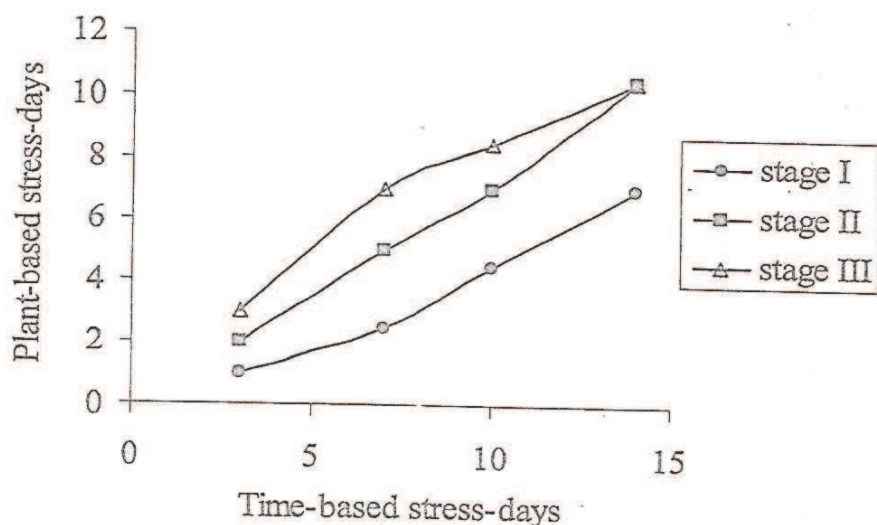


Figure 1: Time-based in relation to plant-based stress-days

Crop Susceptibility (CS) Factors Versus Stress-Day (SD) Factors

The computed crop susceptibility (CS) factors are given in Table 4 and the plot of CS against the plant-based SD factors for the three growth stages is shown in Figure 2. It can be observed from the figure that the CS of a particular growth stage relative to that of another growth stage depends on the level and duration of water deficit. That is, while one growth stage might be more sensitive to stress at a particular range of SD level, another growth stage might be at a different SD range. This corroborates the conclusion of different researchers, as noted by Datiri (1982).

Table 4: Dry Grain Yield and Calculated Values of Crop Susceptibility Factors (CS)

Treatment	Dry grain yield tha ⁻¹	CS
C	1.38	-
AI	1.36	0.014
BI	1.28	0.075
CI	1.00	0.280
DI	0.56	0.597
AII	1.07	0.222
BII	0.89	0.360
CII	0.73	0.470
DII	0.44	0.675
AIII	1.23	0.110
BIII	1.05	0.241
CIII	0.79	0.431
DIII	0.47	0.656

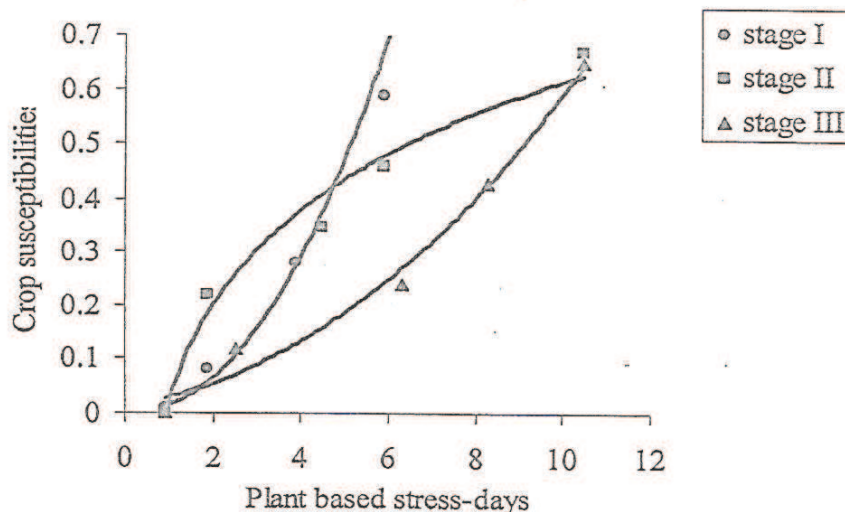


Figure 2: Crop susceptibility in relation to plant-based stress (days)

Also, Figure 2 provides a type of data required for a more precise utilization of the Stress-Day Index (SDI) technique for irrigation timing since it provides CS values not only as a function of growth stage, but also as a function of the degree and duration of the water stress. Therefore, at defined SD, the corresponding CS factors for each growth stage can be obtained from the relevant curve in the figure for use in the SDI irrigation timing technique.

4. Conclusion

The above results show that the relationship between time-intervals, as a stress indicator, and a plant-based stress indicator differ with the crop growth stage. Thus, a time-based stress indicator is not effective with regards to the definition of crop susceptibilities as a function of the timing of occurrence of the crop water stress, except when it is defined in terms of the corresponding values of a defined plant-based value.

Also, the degree and duration of water stress determines not only the magnitude of CS for each growth stage, but also the CS for a growth stage that immediately follows the one in which the water stress was imposed. Thus, it is difficult to advance a unifying theory on CS as a function of only the growth stages of wheat crop in which the water stress is imposed.

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