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Relationship between Flag Leaf Reflectance and Canopy Temperature in Durum Wheat (*Triticum durum* Desf.) Cultivars under Stressed and Irrigated Conditions

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Abstract

Optical technologies can be developed as practical tools for monitoring plant health by providing unique spectral signatures that can be related to specific plant stresses. The objectives of this study were (i) to determine differences in canopy temperature and leaf reflectance of different durum wheat under both well-watered and moisture stressed conditions and (ii) evaluate the relationships between canopy temperature and leaf reflectance at Red and Blue (RB) wavelength. We use numerical image analysis by Mesurim Pro (Version 3.3) softwarefor estimate leaf reflectance at Red and Blue (RB) wavelength.In this study irrigation treatments affect significantly flag leaf reflectance at RB and canopy temperature. Significant correlations were registered between leaf reflectance and canopy temperature under both conditions irrigated and non irrigated; these best correlations proved the efficiency of using leaf reflectance at RB in screening for drought tolerance in durum wheat cultivars.

Key words: Durumwheat, leaf reflectance, canopy temperature, irrigation, drought.

Introduction

Canopy spectral reflectance provides an important method for plant canopy study under different environmental conditions. Multispectral analysis has been widely used for determining canopy responses to environmental stresses, primarily by measuring variations of canopy reflectance from visible or/and near infrared wavelengths(Carter et al., 1996; Huang et al., 1998;Penuelas et al., 1997). The changes in canopy reflectance at a single wave length, a defined wavelength band, or various indices have been used to identify a correlation with canopy variables such as pigment content, photochemical activity, green biomass, and water content(Gamon and Surfus, 1999; Lorenzen and Jensen, 1988). Recently, digital imagery has become a new trend in plant color analysis. Digital cameras or scanners in combination with computers and appropriate software can be used to photograph, scan, and evaluate leaves for color with relative ease and at an affordable cost.In agriculture, digital technology has been used to characterize color in apples(Schrevens and Raeymaeckers, 1992), distinguish weeds from crops (Perez et al., 2000), evaluate senescence rates in spring wheat(Adamsen et al., 1999) and durum wheat (Guendouz and Maamari, 2011; Hafsi et al., 2000) Canopy temperature measurements have been widely used in recent years to study genotypic response to drought. Blum et al. (1989) used canopy temperatures of drought stresses wheat genotypes to characterize yield stability under various moisture conditions. Result from several recent studies show that canopy temperatures under well-watered conditions also provide an indication of potential yield performance during drought and could effectively be used as a technique to assess genotypic response to drought.Rashid et al. (1999) reported that significant correlation between canopy temperature and yield under moisture-stress conditions and stress susceptibility index values indicated the potential for screening wheat genotypes for drought response. Canopy temperature depression, the difference between air temperature (Ta) and canopy temperature (Tc), is positive when the canopy is cooler than the air (CTD = Ta – Tc). It has been used in various practical applications including evaluation of plant response to environmental stress(Howell et al., 1986; Idso, 1982), to evaluate cultivars for water use (Pinter et al., 1990), tolerance to heat (Amani et al., 1996) and drought (Blum et al., 1989).Therefore, the objectives of this study were (i) to determine differences in canopy temperature and leaf reflectance of different durum wheat under both well-watered and moisture stressed conditions and (ii) evaluate the relationships between canopy temperature and leaf reflectance at Red andBlue(RB) wavelength.

Materials and Methods

Ten durum wheat (*Triticum durum* Desf.) were chosen for study based on their reputed differences in yield performance under irrigated and non-irrigated conditions (Table 1). Experiments were conducted at experimental field of ITGC (Technical Institute of Field Crops) station of Setif, Algeria (5°20’E, 36°8’N, 958 m above mean sea level).Genotypes were grown in randomized block design with four replicates. Plots were 2.5 m × 6 rows with 0.20 m row spacing and sowing density was adjusted to 300 g m^{-2}. All plots of the irrigation experiment were irrigated by using a Sprinklers system and the volume of water input for each plot was controlled. Two irrigation regimes were applied; the first irrigation (15 mm) was performed at the time of heading (50 Zadoks cods), and the second irrigation (25 mm) was applied at grain filling period (70 Zadoks cods).A handheld infrared thermometer (Model TECPEL 513, TAIWAN), with a field of view of 100 mm to 1000 mm, was used to measure CT (°C). The data were taken from the same side of each plot at 1m distance from the edge and approximately 50 cm above the canopy at an angle of 30° to the horizontal under both conditions stressed and irrigated. Readings were made between 11:00 and 13:00 h on sunny days. In this study, we use the numerical image analysis (NIA) for estimate the reflectance at Red and Blue(RB) according to Guendouz et al. (2012). Leaves were photographed on white surface, between 11:00 and 13:00 solar time with a color digital camera (Canon, Power Shot A460, AiAF, CHINA). Images were stored in a JPEG (Joint Photographic Expert Group) prior to downloading onto a PC computer and analyzed using Mesurim Pro (Version 3.3) software(Guendouz et al., 2012).

Results and Discussions

Flag Leaf Reflectance

In this study leaf reflectance was measured at Red and Blue, and under stressed and irrigated conditions. As shown in Table 2, and under stressed conditions leaf reflectance at Red is ranged between10.81% for Waha to 46.92% for Oued Zenati with an average of 27.54 % over all genotypes, but under irrigated conditions ranged from 9.46% for Bousselem to 36.35% for Hoggar with an average of 21.22% over all genotypes. The difference between reflectance at Red under irrigated and non irrigated condition is 19.35%, where it shows high mean value under non irrigated condition (Table 2). The ability to assess water stress symptoms in vegetation using spectral reflectance measurements is an important goal for remote sensing research (Jackson et al., 1983). In agricultural crops, it is important to be able to detect the onset of water stress as soon as possible so that preventive measures such as irrigation can be undertaken. The effects of cultivars and irrigation treatment on reflectance at Blue were highly significant. Under non irrigated condition, the percentage of reflectance at Blue ranged from 42.39% for Oued Zenati to 11.05% for Kucuk with an average of 24.99%, but under well watered condition, the reflectance at Blue ranged from 31.32% for Oued Zenati to 8.75% for Polonicum with an average of 18.36%. The highermean value of reflectance at Blue was recorded under stressed condition (Table 2). Water stress can increase reflectance from corn leaves in both visible and infrared portions of the spectrum(Woolley, 1971). Many studies have opened up possibilities that subtle changes in leaf reflectance spectra can be analyzed in a plethora of ways for discriminating nutrient and water stress, but with limited success.

A different approach in analyzing leaf reflectance spectrum employs a color description system that models color perception over the entire visible range. Since many plant stress factors impact on leaf biochemistry and morphology and consequently on reflectance spectral characteristics in the visible range, it follows that these changes can be related to leaf color. Hence, an analysis of stress in terms of leaf colorimetric response represents an entirely valid option (Bacci et al., 1998).

Canopy Temperature

Means related with canopy temperature and canopy temperature depression were given in Table 3. Genotypic variance was significant for CT and CTD under both conditions. The values of canopy temperature (CT) under irrigated condition were ranged between 23.83°C for Sooty to 28°C for Hoggar with an average of 25.99°C over all genotypes, but under stressed condition there is augmentation in the values where ranged from 27°C for Polonicum to 30.66°C for Altar with an average of 28.77°C over all genotypes. The difference between CT under stressed and irrigated conditions equal 10.69%, this result is in agreement with the finding of Talebi (2011), water stress affect positively canopy temperature.

Blum et al. (1989) used canopy temperatures of drought stresses wheat genotypes to characterize yield stability under various moisture conditions. Values of Canopy temperature depression (CTD) ranged between -0.36°C for Mexicali to

2.8°C for Polonicum with an average of 1.016 over all genotypes in stressed conditions. Under irrigated conditions CTD varied from 1.8°C for Hoggar to 5.96°C for Sooty with an average of 3.79°C over all genotypes tested. Drought stressed plants displayed higher canopy temperatures than well-watered plants(Siddique et al., 2000). High CTD has been used as a selection criterion to improve tolerance to drought and heat (Amani et al., 1996; Ayeneh et al., 2002). The genotypes with negative values of CTD suggest that these genotypes it's very sensitive to water stress. CTD as a tool for predicting performance(Reynolds et al., 1997); Increase in CTD might have occurred due to increased respiration and decreased transpiration resulting from stomatal closure(Siddique et al., 2000).

Correlations among Flag Leaf Reflectance and Canopy Temperature

As shown in table 4, and under non irrigated condition CTD (Canopy Temperature Depression) correlated significantly and negatively with reflectance at Red and Blue (r= -0.31*, r= -0.37*respectively); but under irrigated conditions canopy temperature depression correlated significantly and negatively with leaf reflectance at Red (654 nm). In addition, and under non irrigated conditions there is a significant and positive correlation between canopy temperature (CT) and leaf reflectance at Red and Blue (450 nm) (Table 4).In this study, the best correlation among flag leaf reflectance and canopy temperature compatible with many recent studies; a vast number of studies have enhanced our understanding of the optical properties of leaves and their correlation with plant responses to various stresses. Infrared/near infrared analyses, thermography, chlorophyll fluorescence analyses and transmission/reflectance spectral indices have been used to monitor water status, surface temperature, photosynthetic efficiency and structural changes in plants for early detection of environmental stress responses(Chaerle and Van der Straeten, 2000).

Conclusion

In this study we use numerical image analysis for estimate leaf reflectance at Red and Blue (RB) under irrigated and non irrigated conditions. The results suggest that the irrigation treatments affect negatively the percentage of leaf reflectance (there is a decrease in leaf reflectance under irrigated conditions) and canopy temperature. Canopy temperature and Canopy temperature Depression has been used as a selection criterion to improve tolerance to drought and heat (Amani et al., 1996; Ayeneh et al., 2002);the significant correlation between flag leaf reflectance and canopy temperature proved the efficiency of using leaf reflectance at RB in screening for drought tolerance in durum wheat cultivars.

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Table 1. Name and origin of the ten genotypes used in the study

Cultivar	Name	Origin	Cultivar	Name	Origin
1	Bousselem	Algeria	**6**	Altar	Mexico
2	Hoggar	Algeria	**7**	Dukem	Mexico
3	Oued Zenati	Algeria	**8**	Kucuk	Mexico
4	Polonicum	Algeria	**9**	Mexicali	Mexico
5	Waha	Algeria	**10**	Sooty	Mexico

Table 2. Response of reflectance at Red and Blue of ten durum wheat genotypes tested under irrigated and non irrigated conditions.

	Reflectance at RED		Reflectance at BLUE	
Genotype	Irrigated	Non irrigated	Irrigated	Non irrigated
Bousselem	9,46(i)	29,3(d)	10,03(g)	24,01(d)
Hoggar	36,35(a)	29,5(d)	30,93(a)	29,41(bc)
Oued Zenati	35,27(b)	46,92(a)	31,32(a)	42,39(a)
Polonucum	10,21(h)	34,63(b)	8,57(h)	30,24(b)
Waha	19,25(e)	10,81(h)	16,79(d)	13,20(g)
Altar	16,82(f)	32,21(c)	16,57(d)	28,79(c)
Dukem	17,28(f)	17,6(g)	11,52(f)	18,85(f)
Kucuk	27,98(c)	20,47(f)	22,15(b)	11,05(h)
Mexicali	25,42(d)	26,46(e)	20,76(c)	21,64(e)
Sooty	14,21(g)	27,52(e)	15,01(e)	29,34(bc)
Mean	21,22	27,54	18,36	24,99
Min	9,46	10,81	8,57	11,05
Max	36,35	46,92	31,32	42,39
LSD **0.05**	0,697	1,096	0,705	1,004

Means followed by the same latter are not significantly different at p<0.05.

Table 3. Ranking of tested genotypes for Canopy Temperature Depression (CTD) and Canopy temperature (CT).

	Canopy Temperature Depression		Canopy Temperature	
Genotype	Non Irrigated	Irrigated	Non Irrigated	Irrigated
Oued Zenati	1,13 abcd	3,96 ab	28,66 abcd	25,83 ab
Altar	-0,86 d	2,3 ab	30,66 a	27,5 ab
Sooty	1,63 abc	5,96 a	28,16 bcd	23,83 b
Polonucum	2,8 a	4,13 ab	27 d	25,66 ab
Waha	1,96 ab	4,3 ab	27,83 cd	25,5 ab
Dukem	1,46 abcd	5,3 ab	28,33 abcd	24,5 ab
Mexicali	-0,36 bcd	2,96 ab	30,16 abc	26,83 ab
Kucuk	2,3 a	4,96 ab	27,5 d	24,83 ab
Hoggar	-0,53 cd	1,8 b	30,33 ab	28 a
Bousselem	0,63 abcd	2,3 ab	29,16 abcd	27,5 ab
Mean	1,016	3,797	28,779	25,998
Min	0,36	1,8	27	23,83
Max	2,8	5,96	30,66	28
LSD **0,05**	2.47	3,89	2,47	3,89

Means followed by the same latter are not significantly different at $p<0.05$.

Table 4. Correlation between Flag leaf reflectance and Canopy Temperature under irrigated and non irrigated conditions.

	CTD_{NI}	CTD_{I}	CT_{NI}	CT_{I}
Red_{I}	-0,23	-0,31*	0,23	0,31*
Red_{NI}	-0,31*	-0,21	0,31*	0,2
$Blue_{I}$	-0,26	-0,24	0,25	0,23
$Blue_{NI}$	-0,37*	-0,27	0,37*	0,27

CTD: Canopy Temperature Depression, **CT:** Canopy Temperature
I: irrigated, **NI:** non irrigated. **Red** and **Blue**: Reflectance at Red and Blue (654 nm and 450 nm respectively).