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Canopy Temperature : A Method to Estimate Plant Water Stress and Scheduling Irrigation in Cotton and Wheat

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ABSTRACT

A two year field study was conducted on a sandy loam soil at PAU, Regional Station, Bathinda to study canopy temperature measurement as a rapid method to estimate plant water status in cotton and wheat crops. The canopy temperature of the stressed wheat crop, where no irrigation was applied remained about 1°C higher as compared to unstressed crop, where all the irrigations were applied as per recommended schedule. However, no difference in canopy temperature of the stressed and unstressed cotton crop was observed during the study. The canopy air temperature differences (CATD) explain 35 and 17 per cent variation in the yield of wheat and American cotton, respectively. The profile water storage explained 55 and 53 per cent variation in the canopy temperature of wheat and American cotton, respectively. The canopy temperature and canopy air temperature difference (CATD) could not appreciably explain the variation in seed cotton yield of A. cotton during both the years, but significantly explained the wheat grain yield. In wheat crop, the highest water expense efficiency was recorded under moderate and optimum irrigated crop.

Introduction

Canopy temperature is related to plant water stress because the evaporative cooling involved in transpiration may cool leaves below ambient air temperature. If soil water is limiting, plant water stress develops, transpiration decreases and the canopy temperature rises. Canopy temperature of the crop can be used as indicator of the crop water stress. Canopy temperature and canopy air temperature difference (CATD) are directly related to the amount of water present in the plant. Crops with adequate supply of water are maintained below air temperature, whereas those lacking water rises above air temperature. Remote measurement of the leaf temperature offers a quick means of evaluating plant water stress (Jackson *et.al.* 1977). Weigand and Namken (1966) also proposed canopy-air temperature difference (CATD) to be an indicator of crop water stress. Das *et al.* (1985) also reported that CATD values for wheat were higher under unirrigated conditions than under irrigated conditions throughout the growing season of the crop. The present paper briefly presents some results to demonstrate the potentiality of remote sensing techniques in monitoring crop water stress and scheduling of irrigation to crops.

Materials and Methods

A two year field study was conducted during 1998-2000 at Punjab Agricultural University, Regional Station, Bathinda to study the relationship between canopy temperature, canopy air temperature difference and yield of wheat and American cotton grown under various irrigation treatments. The experiment was laid out in randomized block design (RBD) with four replications. The treatments in the wheat were stressed (T_1), moderately stressed (T_2) and unstressed (T_3). In stressed crop, no post sowing irrigation was applied; whereas in case of moderately stressed treatment only one irrigation at CRI stage was applied, and in unstressed treatment , optimum irrigations were applied at all the stages of the crop and no water stress was faced by the crop. In American cotton, the treatments consisted of stressed (T_1), moderately stressed (T_2) and unstressed (T_3). In stressed crop no post sowing irrigation was applied, whereas in case of moderately stressed treatment only one irrigation was applied, and in unstressed treatment three irrigations were applied at all the stages i.e., 4 weeks after sowing, flowering and fruiting stage of the crop and no water stress was faced by the crop. The experiment details are given in Table 1.

Table 1. Details of experiment sown during 1998-2000

Year	Crop	Variety sown	Date of sowing	Date of harvesting	Irrigations
1998	A. cotton	F 1378	18.5.98	25.10.98	T1: Nil T2: 18/6/98 T3: 18/6. 27/8, 10/9
1998	A. cotton	F 1378	26.5.99	25.10.99	T1 : NIl T2 : 18/8/98 T3 : 7/7, 11/8, 5/9
1998-99	Wheat	PBW 373	20.11.98	10.4.99	T1 : Nil T2 : 17/12 T3 : 17/12, 19/1, 1/3
1999-2000	Wheat	PBW 373	16.11.99	13.4.00	T1 : Nil T2 : 16/12 T3 : 16/12, 19/1, 1/3

The canopy temperature and canopy air temperature difference (CATD) were recorded by using AG-42 infrared thermometer with 0.5°C accuracy and 0.1°C resolution. The canopy temperature and CATD data were recorded from 15 September onwards in A. cotton and from January onwards in wheat on alternate days, as well as before and after each irrigation . The soil moisture determined thermo gravimetrically from the 0-180 cm soil profile.

Results and Discussion

Wheat

The grain yield of wheat increased significantly with the application of one irrigation (T_2) as compared to no irrigation (T_1) during both the years of study (Table 2). The mean grain yield recorded in no irrigation was 1460 kg/ha as compared to 2410 kg/ha recorded by applying only one irrigation. The grain yield of wheat can be increased significantly by applying three irrigations as compared to one irrigation. The increase in grain yield may be due to more plant height and more number of tillers per metre row length (Table 2) recorded in unstressed crop (T_3) as compared to stressed crop (T_1). The low yield recorded in stressed crop (T_1) mainly due to moisture stress accompanied by the low uptake of nutrients under stress conditions. The mean water expense efficiency (WEE) recorded was almost same in moderately stressed (74.7 kg/ha-cm) as well as unstressed crop (75.5 kg/ha-cm), although the water expense was much higher in unstressed crop (47.8 cm) as compared to moderately stressed (32.7 cm) and unstressed (29.1 cm) crop .The higher yield recorded under unstressed conditions resulted in higher water expense efficiency (Table 3). The canopy temperature of stressed crop remained higher as compared to unstressed crop. The relationships between grain yield, canopy temperature , canopy air temperature difference (CATD) and profile water storage (PWS) are given below:

Wheat yield = 4615.4-686.8 X CATD (R^2=0.35) (1998-99 and 1999-2000)

Canopy temperature (wheat) = 70.12-1.94 X PWS (R^2=0.55) (1998-99 and 1999-2000)

The above equation shows that the CATD explained 35 per cent variation in grain yield of wheat. The profile water storage explained 55 per cent variation in canopy temperature of wheat crop. It showed that canopy temperature of wheat significantly depends on the moisture present in the soil profile. Das *et al.* (1985) reported that CATD values for wheat under unirrigated conditions were higher than under irrigated conditions throughout the growing season of the crop. Similar findings in

Table 2. Effect of different irrigation treatements on yield attributing characters and grain yield of wheat

Treatments	Plant height (cm)			Tillers per meter (no.)			Graint yield (kg/ha)		
	1998-99	1999-00	Mean	1998-99	1999-00	Mean	1998-99	1999-00	Mean
T_1 (Stressed)	67.5	65.5	66.5	31.8	60.3	46.1	1590	1330	1460
T_2 (Moderately stressed)	80.7	90.7	85.7	40.4	92.8	66.6	2140	2680	2410
T_3 (unstressed)	87.5	98.3	92.9	43.1	94.0	68.8	3270	3600	3435
C.D. 5%	7.0	7.5	-	8.7	10.5	-	480	440	-

Table 3. Effect of different irrigation treatements on irrigation water applied, profile moisture use, water expense, water expense efficiency in wheat

Treat-ments	Irrigation water applied (cm)			Profile moisture use (cm)			Water expense (cm)			Water expense efficiency (kg/ha-cm)		
	98-99	99-00	Mean	98-99	99-00	Mean	98-99	99-00	Mean	98-99	99-00	Mean
T_1 (stressed)	-	-	-	23.1	23.4	23.3	30.8	27.3	29.1	51.6	48.7	50.2
T_2 (Mode-rately stressed)	7.5	7.5	7.5	18.3	19.0	18.7	34.9	30.4	32.7	61.3	88.1	74.7
T_3 (Un-stressed)	22.5	22.5	22.5	19.2	19 8	19.5	48.5	46.0	47.8	78.2	72.8	75.5

Table 4. Effect of different irrigation treatments of yield attributing characters and seed Cotton yield of American cotton

Treat-ments	Monopods per plant (no.)			Sympods per plant (no.)			Bolls per plant (no.)			Seed cotton yield (kg/ha)		
	98-99	99-00	Mean	98-99	99-00	Mean	98-99	99-00	Mean	98-99	99-00	Mean
T_1 (Stressed)	10.6	6.9	8.8	0.9	0.6	0.8	12.0	6.7	9.4	304	275	290
T_2 (Mode-rately stressed)	10.9	8.6	9.8	1.5	1.0	1.3	12.9	7.9	10.4	375	331	353
T_3 (Un-stressed)	10.6	9.4	10.0	0.8	1.8	1.3	10.9	9.7	10.3	426	357	392
C.D. 5%	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-

Table 5. Effect of different irrigation treatments on irrigation water applied, profile moisture use, water expense, water expense efficiency in American cotton

Treat-ments	Irrigation water applied (cm)			Profile moisture use (cm)			Water expense (cm)			Water expense efficiency (kg/ha-cm)		
	98-99	99-00	Mean	98-99	99-00	Mean	98-99	99-00	Mean	98-99	99-00	Mean
T_1 (Stressed)	-	-	-	6.7	7.9	7.3	65.0	23.4	44.2	4.7	11.8	8.3
T_2 (Moderately stressed)	7.5	7.5	7.5	3.9	11.4	7.7	69.7	34.3	52.0	5.4	9.7	7.6
T_3 (Un-stressed)	22.5	22.5	22.5	4.2	9.1	6.7	85.0	47.0	66.0	5.0	7.6	6.3

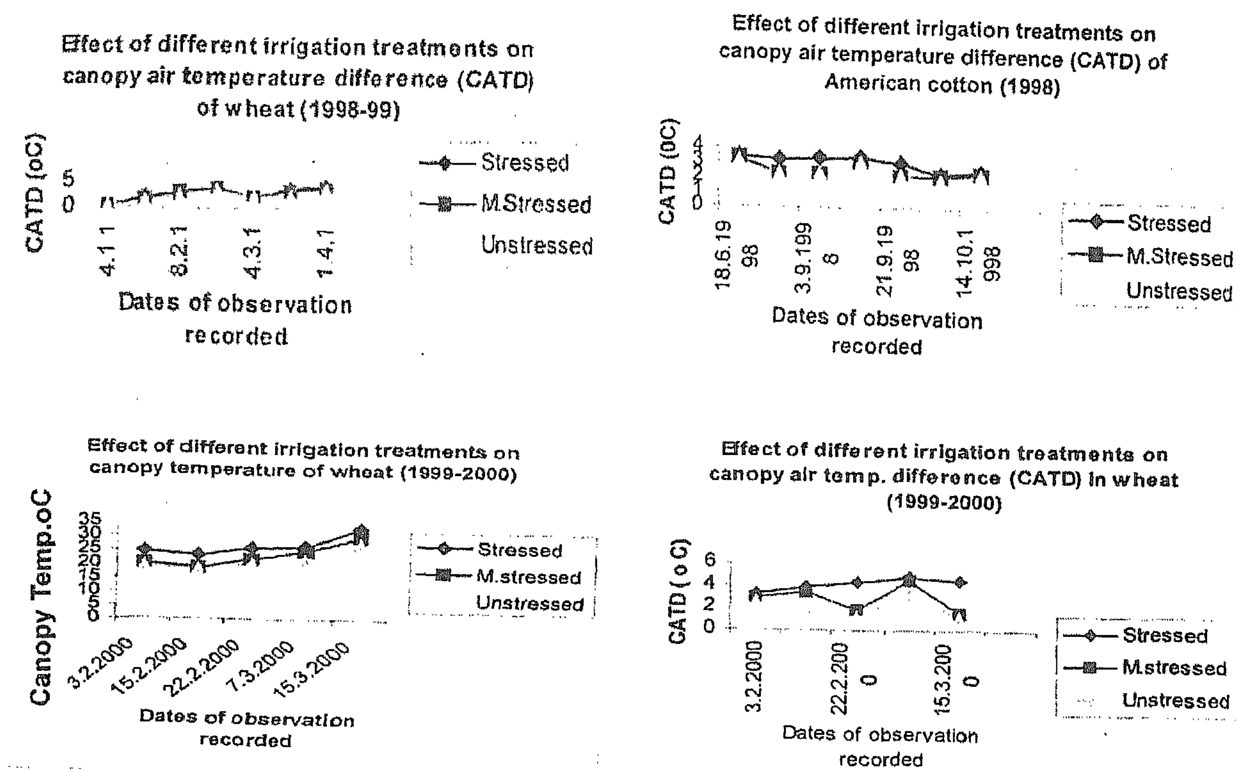

Fig. 1.

canopy temperature and CATD in wheat under different irrigation treatments are shown in Fig 1.

American Cotton

The seed cotton yield of A. cotton increased with the application of one (T_2) and three irrigations (T_3) as compared to no post sowing irrigation (T_1), but the differences were significantly non significant during both the years. Although the number of monopods , sympods and bolls per plant increased with the application of one and three irrigations (Table 4) , but the differences were non significant. The water expense was much higher under unstressed crop (66.0 cm) as compared to stressed crop (44.2 cm). There was not much difference in water expense efficiency (Table 5) under different treatments. This may be due to sufficient moisture present in the soil profile due to rains, so irrigation

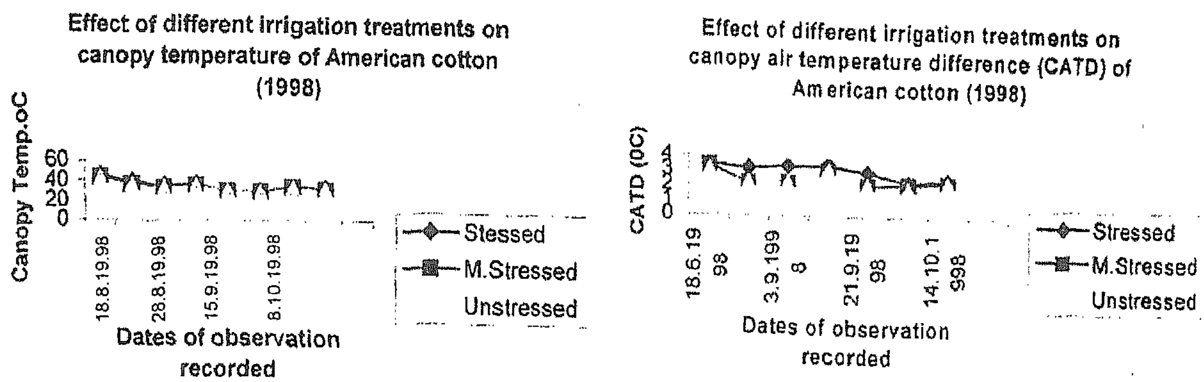

Fig. 2.

treatments have not significant effect on the crop yield. The low seed cotton yield was due to epidemic attack of American bollworm on the cotton crop in the whole Punjab state during both the years.

The relationships between seed cotton yield, canopy temperature, canopy air temperature difference (CATD) and profile water storage (PWS) are given below:

American cotton yield = 144.406 + 0.9849 X CATD (R^2=0.017) (1998 and 1999)

Canopy temperature (American cotton) = 4.244 + 0.1938 X PWS (R^2=0.53) (1998 and 1999)

The above equation showed that the contribution of CATD towards seed cotton yield were non significant (0.17 %). However, the profile water storage explained 53 per cent the canopy temperature variation in American cotton. Due to rainy season crop, the effect of different irrigation treatments is non significant. The canopy temperature of stressed crop remained slightly higher than unstressed crop. Wiegand and Namken (1966) reported that leaf temperature of cotton will rise above air temperature when the soil moisture is limiting. But due to sufficient rainfall, during both the years, during the crop season of American cotton, the differences were non significant. The differences in canopy temperature and CATD in American cotton under different irrigation treatments during 1998 are shown in Fig 2.

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Plant Water Relations, Solar Radiation Interception, and Wheat Performance as Influenced by Crop Establishment Methods and Nitrogen Under Extreme Winter Precipitation

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ABSTRACT

Field study was conducted at PDCSR, Modipuram (U.P.) in well drained sandy loam soil (Typic Ustochrept) in pigeon pea based cropping system with wheat (cv. PBW-226) in split-plot design. Treatments consisted of three planting geometry (main-plot) viz., bed planting system (M_1), paired row system of planting (M_2) and conventional planting (M_3) and four levels of nitrogen (sub-plot) viz., 0 (N_0), 60 (N_1), 120 (N_2), and 180 (N_3) kg ha^{-1} were replicated thrice. Due to exceptionally very high and well distributed precipitation of 168.2 mm between the harvest of preceding short duration pigeon pea and sowing of next wheat, it could be planted very late in the first week of January without pre-sowing irrigation. Crop emergence was delayed considerably and could be initiated on 12th day and completed by 18th day after sowing due to excessive soil moisture. Relatively higher soil moisture content in the profile was found in M_3 compared to M_2 and it was appreciably higher in N_0 compared to N_3. Higher xylem water potential (XWP) was observed in M_1 compared to M_2 and was maximum in N_0 and the minimum in N_3. Highest solar radiation interception was found in M_3 and the lowest in M_2 and appreciably higher in N_3 than N_0. Crop growth was superior in M_3 over M_2 and considerably higher in N_3 compared to N_0. There was a net saving of 49.1% of water in M_1 compared to M_3. Substantially higher grain yield (27.9%) was recorded in M_3 compared to M_2. Almost doubling of yield (97.6%) was found in N_3 over N_0.

Key words: Xylem water potential, radiation parameters, crop establishment methods, N-nutrition, wheat, excessive winter precipitation.

Introduction

Water and nitrogen are the most limiting factor affecting the plant water relations and the crop performance. Wheat is the staple food of our country, which is grown in diverse situations from rain fed to irrigated conditions. However, more than 85% wheat area is irrigated. Water and nitrogen use efficiency of this crop is low and there is lot of scope for its improvement. Crop establishment methods, nutrient management and type of the preceding crops considerably influence the performance of the succeeding crop in the system. Wheat crop can be planted by several methods viz., conventional, paired rows and bed planting/ridge techniques. There are reports that wheat sowing on flat beds leads to considerable saving in irrigation water. Recent studies showed that crops like wheat maize, soybean, cotton and few vegetables could also be grown on beds. This may reduce water and fertilizer inputs as compared with conventional system. Bed-furrow system reduces irrigation requirement as water is applied in furrows only instead of irrigating the entire field. This technology was well adopted by small-scale wheat growers in Yaqui valley of Sonara state of NW Mexico (Aqiuno, 1998; Sayre, 1999) and thus has emerged as one of the promising suitable crop management techniques. This technique has the advantage of reducing fuel, water, labour and fertilizer inputs compared to conventional system (Limon *et al.* 2000). Keeping in view the increasing scarcity of