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Influence of water stress in wheat crop yield

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सार — पैदावार, शुष्क पदार्थ उत्पादन, जल उपयोग क्षमता और वर्ग क्षेत्र सूचकांक पर सिचाई के विभिन्न स्तरों के प्रभाव का अध्ययन किया गया। वितान तापमान जैसे वितान तापमान, दाब डिग्री दिनों और फसल जल दाब सूचकांक से व्युत्पन्न तीन संचित दाब घातांकों पर विभिन्न सिचाई के अन्तर्गत प्रयुक्त जल के उपयोग के सम्बंध का सार्थक होना पाया गया। अनाज की अन्तिम पैदावार इन घातांकों के साथ महत्वपूर्ण रूप में सह-सम्बंधित थी। यह विचार किया गया कि प्रचालन अनुप्रयोगों के लिए बड़े पैमाने पर किसानों के खेतों पर फसल की पैदावार की प्रागुक्ति के लिए इन घातांकों का उपयोग किया जा सकता है।

ABSTRACT. Effect of different irrigation levels on yield, dry matter production, water use efficiency and leaf area index were studied. Relationship of water use under differential irrigation was found to be significant on three accumulated stress indices derived from canopy temperature, *viz.*, canopy temperature, stress degree days and crop water stress index. Final grain yields were significantly correlated with these indices. It was envisaged that these indices can be exploited for crop yield prediction at large scale farmer's field for operational applications.

1. Introduction

Wheat crop grown in arid and semi-arid regions generally faces water stress at one stage or the other due to shortage of irrigation facilities. Measurement of this stress and quantification of its effects on crop yields can serve for better management of the limited irrigation resources available and for estimation of crop yields in the light of stress faced by the crop.

It is known that plant water stress is primarily governed by soil moisture regimes and environmental parameters and has direct bearing on stomatal closure. This causes a rise in canopy temperature due to reduced transpirational cooling which can be detected remotely by using infrared thermometers. Accumulation of daily values of canopy temperature have been used for estimation of evapotranspiration or water use by the crop (Heilman *et al.* 1976 and Jackson *et al.* 1977).

The present study was, therefore, conducted with the objective of formulating empirical relationships between water use and canopy temperature derived stress indices in wheat crop. Growth and yield of wheat crop under different moisture levels was also studied.

2. Material and methods

A field experiment was conducted during *rabi*, 1986-87 using wheat (*Triticum aestivum L.*) variety WH-283 on the sandy loam soils at the research farm of Haryana Agricultural University, Hisar. Four different moisture stress levels were created by supplying different irrigations as :

(*i*) No post-sowing irrigations - T_1,

(*ii*) One post sowing irrigation at crown root initiation stage (CRI) - T_2,

(*iii*) Two post sowing irrigations at CRI and flowering stage - T_3 and

(*iv*) Four post sowing irrigations at CRI, jointing flowering and dough stages - T_4

Pre-sowing irrigation was applied to all the treatments and each treatment was replicated four times. Plot size was 10.8 m × 6.0 m.

Soil moisture, leaf area index and dry matter were recorded /computed at 15 days interval from sowing to harvesting. Soil moisture was computed with the help of gravimetric method up to a depth of 120 cm, whereas leaf area of plants in a unit area was measured with the help of leaf area meter. Plant samples were oven dried to obtain dry matter production. Crop canopy temperatures and their difference with ambient air temperature were recorded daily between 1300 and 1400 IST from 40 days after sowing (DAS) up to maturity with the help of infrared thermometer. Four observations from each plot were used to compute average canopy temperature and its difference with ambient air temperature.

Three moisture stress indices were used to explain the crop water use variability, *viz.*, canopy temperature (T_c), stress degree day (SDD) concept of Idso *et al.* (1977) and crop water stress index (CWSI) of Idso *et al.* (1981). Cumulative values of these indices over different time periods were correlated with grain yields through linear regressions to obtain empirical relationships between them. Sixteen observations were used for computation of regression equations.

TABLE 1

Effect of different irrigations on leaf area index (LAI), dry matter production (DM), grain yield and water use efficiency (WUE) in wheat

Treatment	Average water use (mm)	Maximum LAI	DM (q/ha)	Grain yield (q/ha)	WUE (q/ha-cm)
T_1	152.0	2.69	90.64	21.76	1.43
T_2	212.0	3.50	99.08	25.39	1.20
T_3	299.0	3.73	100.56	28.24	0.94
T_4	425.0	4.25	108.48	38.97	0.92
(SEm)(±)		0.16	2.02	0.80	0.04
CD at 5%		0.50	6.45	2.57	0.12

SE_m — Mean standard error,

C D — Coefficient of determination.

During the crop season, the maximum and minimum temperature varied from 18.0° to 39.6° C and 0.7° to 15.5°C respectively. The total rainfall during the season was 72.0 mm against a normal seasonal rainfall of 50 mm.

3. Results and discussion

3. 1. *Effect of irrigation on leaf area index, dry matter production, grain yield and water use efficiency*

Grain yield increased significantly with increase in levels of irrigation (Table 1). On an average T_2, T_3 and T_4 treatments increased grain yield by 16.7, 29.8 and 79.1 per cent respectively, over the T_1 treatment. The total dry matter (DM) production in irrigated treatments (T_2, T_3 and T_4) was significantly higher than that of the unirrigated treatment (T_1). The DM production did not differ significantly between T_2 (one irrigation at CRI stage) and T_3 (two irrigation one each at CRI and flowering stage), whereas grain yield of T_3 was significantly higher than that of T_2 treatment. It showed the importance of irrigation in wheat at flowering stage. It might have happened due to better translocation of photosynthetes generated in vegetative parts towards development of the grains because of availability of more water at flowering stage. On the other hand, the photosynthetes produced in the plants of T_2 treatment could not be efficiently translocated towards the grains and were forced to accumulate inside the vegetative parts where they were generated. As a result the total DM production did not vary much between the two treatments whereas the grain yield differed significantly between these.

Water use efficiency (WUE) decreased significantly with increase in the number of irrigations. T_1 had significantly higher WUE (1.43 q/ha-cm) than all other treatments. WUE of T_2 (1.20 q/ha-cm) was also significantly higher than those of T_3 (0.94 q/ha-cm) and T_4 treatment (0.92 q/ha-cm). However, the difference between WUE of T_3 and T_4 treatments was non-significant.

Table 1 also shows that maximum leaf area index (LAI) was significantly different among different treatments except between T_2 and T_3 treatments. Maximum LAI increased with increase in number of irrigations up to four irrigations. Fig. 1 depicts the march of LAI with days after sowing (DAS). It increased slowly up to 35 DAS, and then increased at a faster rate, though the increase in T_1 was at a comparatively slower rate. It reached maximum around 84 DAS, after which it decreased due to yellowing of the lower leaves. Greater LAI in T_4 would have resulted in great photosynthetic activity and thus higher yields.

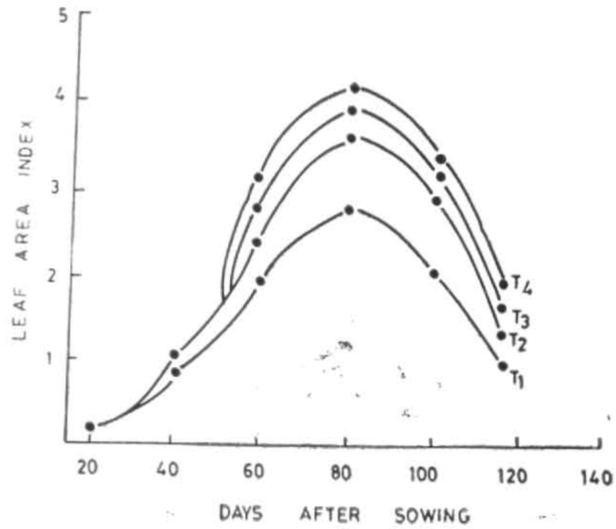

Fig. 1. Leaf area index as a function of days after sowing in differentially irrigated wheat

TABLE 2

Accumulated values of various stress indices under different irrigation treatments

Treatment	Tc (°C)	SDD (°C)	CWSI
T_1	2380.0	31.92	48.30
T_2	2273.0	—130.83	27.96
T_3	2236.0	—170.22	22.84
T_4	2164.0	—271.41	13.93

3.2. *Stress indices and water use*

Values of canopy temperature (T_c) stress degree days (SDD) and crop water stress index (CWSI) accumulated from 40 DAS to maturity of the crop (135 DAS),are presented in Table 2. Cumulative values of T_c are highest in the most stress treatment (T_1) and lowest in the least stressed (T_4). This is because of smaller quantity of available net radiation being utilized towards latent heat of evaporation in T_1 as compared to other treatments. Therefore, heat load over the canopy might have increased T_c in T_1, compared to the other treatments and, therefore, the highest accumulated values of it in T_1 and decreased with reduction in water stress. Similarly the cumulative values of CWSI where highest in T_1 treatment and decreased with decrease in water stress up to T_4.

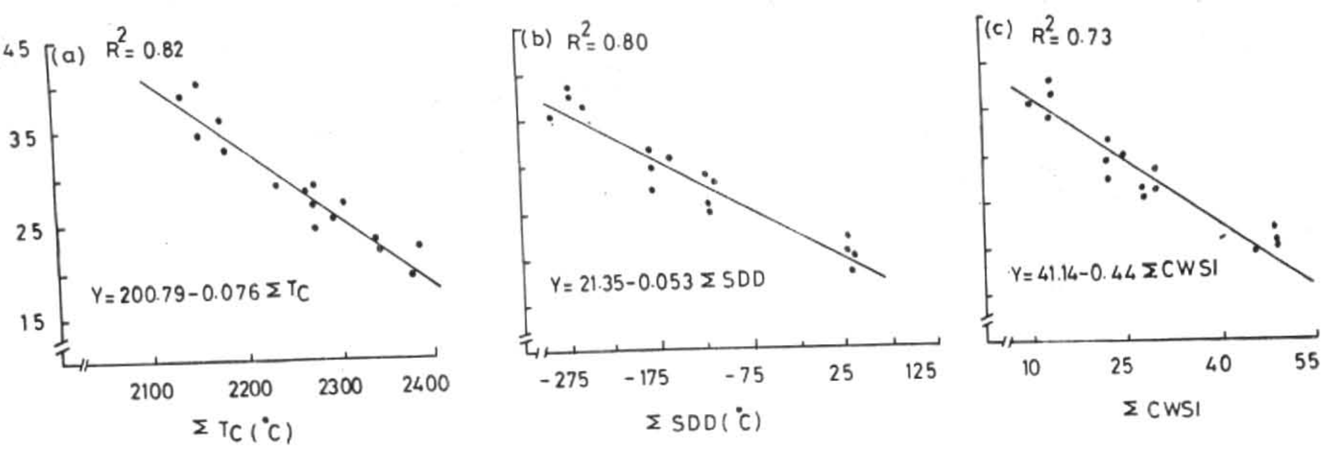

Fig. 2. Relationships of grain yield with accumulated : (a) *Tc*, (b) SDD and (c) CWSI in differentially irrigated wheat

TABLE 3

Relationship of grain yields with the stress indices accumulated over different time intervals

Time interval for accumulation of the indices (DAS) (1)	*Tc* Regression (2)	R^2	SDD Regression (3)	R^2	CWS Regression (4)	R^2
41-60	136.34 — 0.278*X*	0.48	20.54 — 0.297*X*	0.51	35.18 — 1.884*X*	0.36
61-80	178.65 — 0.375*X*	0.69	13.14 — 0.272 *X*	0.77	35.84 — 2.738*X*	0.72
81-100	474.22 — 0.982*X*	0.95	18.25 — 0.265 *X*	0.71	42.19 — 2.005*X*	0.67
101-120	151.85 — 0.246*X*	0.82	24.26 — 0.187*X*	0.79	37.13 — 1.305*X*	0.74
41-80	157.28 — 0.163*X*	0.58	16.25 — 0.147 *X*	0.67	35.94 — 1.195*X*	0.55
61-100	287.06 — 0.303*X*	0.85	15.68 — 0.135*X*	0.75	39.52 — 1.159*X*	0.70
81-120	225.61 — 0.206*X*	0.86	21.72 — 0.110*X*	0.76	39.27 — 0.802*X*	0.72

where, *X* is *Tc* or SDD or CWSI accumulated over the period indicated in column 1.

Cumulative values of SDD (canopy air temperature difference) also decreased from T_1 to T_4. This was because lower availability of water in T_1 (due to restricted irrigation) limited the transpiration rate and, therefore, there was less transpirational cooling of the canopy as compared to other treatments. Thus, the cumulative value of SDD was highest in T_1 and decreased with decrease in water stress up to T_4 treatment.

It was, thus, observed that these stress indices indicated the amount of water used (W_u) by the crops. Cumulative values of these stress indices (accumulated from 40 DAS to maturity) had highly significant correlations with W_u of the crop. These relationships are given below :

$$W_u = 3417.0 - 1.389\, X_1 \; (r = 0.95^{**})$$
$$W_u = 136.74 - 1.001\, X_2 \; (r = 0.94^{**})$$
$$W_u = 524.64 - 8.929\, X_3 \; (r = 0.91^{**})$$

where, W_u is total water use by the crop in mm,

X_1 is accumulated T_c in °C,

X_2 is accumulated SDD in °C,

X_3 is accumulated CWSI.

**Significant at 1% level of probability.

These results are in conformity with those reported by Brown (1974) for corn and Jackson *et al.* (1977) for wheat.

3.3. *Stress indices and crop yields*

Final grain yields were found to have strong linear relationships with accumulated values of the stress indices. These results presented in Fig. 2 showed that accumulated values of T_c, SDD and CWSI respectively, explain 82, 80 and 73 per cent variability in grain yields. Similar results have been reported by Idso *et al.* (1977) for wheat crop.

The relationship between the stress indices and yields can be explained on the grounds that canopy temperature increased due to reduced transpirational cooling caused by stomatal closure. This closure of the stomata hinders CO_2 exchange and CO_2 assimilation and thus affects the crop yields.

Accumulation of these stress indices over different time intervals was used for predicting the final grain yields and the prediction equations obtained are presented in Table 3.

It is evident from the table that final grain yields can be predicted well in advance with the help of these stress indices. Accumulated values of these stress indices in the pre-anthesis stage (anthesis accrued between 82 and 85 DAS in all the treatments) could predict grain yield to a lower extent as compared to when they were accumulated over anthesis (flowering) and post anthesis stages. The maximum variability in grain yield (95%) was explained by T_c when accumulated from 81 to 100 DAS.

Idso *et al.* (1977) have also reported that grain yields had very strong correlations with accumulation of SDD over different intervals in wheat crop.

4. Conclusions

It may be concluded that, (*i*) Flowering is a very critical stage for irrigation in wheat crop, (*ii*) Accumulated values of T_c, SDD and CWSI can be used for estimation of water use of the crop and grain yields and (*iii*) The indices can also be exploited for prediction of grain yields when accumulated over flowering and post flowering stages.

References

Brown, K.W., 1974, "Calculations of evapotranspiration from crop surface temperature," *Agric. Met.*, **14**, 199-209.

Heilman, J.L., Kanemasu, E.T., Rosenberg, N.J. and Blad, B.L., 1976, "Thermal scanner measurement of canopy temperature to estimate evapotranspiration", *Remote Sens. Environ.*, **5**, 137-145.

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., 1981, 'Foliage ' and air temperature: Evidence for dynamic "equivalent point", *Agric. Met.*, **24**, 223-226.

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.