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Behaviour of relative evapotranspiration with agrometeorological stress indices in wheat

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सार — समय से पहले और बाद में बोए जाने वाली गेहूं की फसल में सापेक्ष वाष्पोत्सर्जन के साथ प्रतिबल सूचकांकों का जटिल व्यवहार देखा गया, जबकि गेहूं बोए जाने की सामान्य दशाओं में इसमें रेखीय कमी पाई गई। गेहूं की फसल में, प्रतिबल की दशाओं में, पौधे में ''केनौपी'' तापमान और स्टोमी अवरोध की तुलना में आंतरिक नमी की स्थिति अभिलक्षित करने के लिए पौ फूटने से पहले पत्तों का जल-विभव और उत्सर्जन दर स्थिर प्रतिबल सूचकांक के प्राचल सिद्ध हुए हैं। चूंकि ''केनौपी'' के तापमान को मात्रात्मक रूप में प्रकट करना आसान है, अतः मौसमी परिवर्तनों के दौरान गेहूं की बढ़वार और विकास पर नमी के प्रतिबल के प्रभाव को मात्रात्मक रूप में प्रकट करने तथा सिंचाई सुनियोजित करने के लिए इसका व्यापक प्रयोग किया जाता है।

ABSTRACT. Complex behaviour of stress indices with relative evapotranspiration was observed in early and late sown wheat, however, under normal sown conditions it was linearly decreasing. Predawn leaf water potential and transpiration rate proved to be a stable stress index parameter for characterising the internal moisture status in the plant as compared to the canopy temperature and stomatal resistance under stress conditions in wheat. Since it is easy to quantify canopy/leaf temperature and within seasonal variations it is widely used for scheduling irrigation and quantifying moisture stress effects on growth and development in wheat.

Key words—Stress indices, Relative evapotranspiration (RET), Soil moisture, Canopy temperature.

1. Introduction

The ratio of actual to potential evapotranspiration, termed as relative evapotranspiration has been used by several workers with different nomenclature as stress indices in crop production aspects (Veihmeyer and Hendrickson 1955, Pierce 1958, Thornthwaite and Mather 1955, Van Bavel 1953, Holmes and Robertson 1963, Philip 1957, Dale and Shaw 1965, and Stanhill 1961).

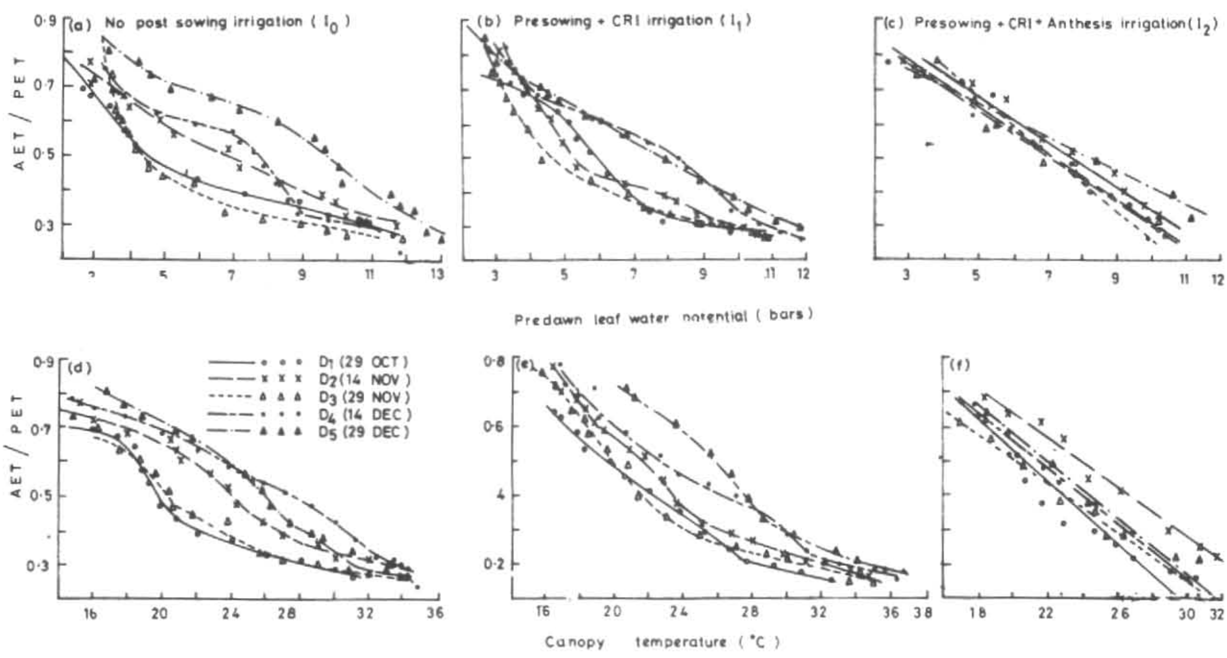
In the present paper attemps have been made to study the behaviour of relative evapotranspiration with these stress indices in order to quantify the actual moisture status in plants influencing the yield attributes. This moisture adequacy index has potentiality to estimate the agricultural potential in terms of irrigation requirement, land use planning and formulation of cropping patterns to make best use of available resources.

Stress indices based on canopy temperature and internal moisture status as leaf water potential (Meyer and Green 1980, Hall and Larson 1982), canopy temperature (Idso *et al.* 1977, Idso *et al.* 1981, Jackson *et al.* 1977, Turk and Hall 1980), and transpiration rate (Rosenberg *et al.* 1983, Salime and Todd 1965) have been used to explain the variability in yield attributes and scheduling of irrigation.

2. Material and method

A field experiment was conducted with wheat variety (WH-147) with five dates of sowings D_1 to D_5 (29 October, 14 & 29 November, and 14 & 29 December) and three levels of irrigations (I_0 — presowing, I_1 — presowing + CRI, I_2 — presowing + CRI + Anthesis) in split plot design with 3 replications during 1990-1991 and 1991-1992. Row spacing was 22.5 cm with N-S orientation having a gross plot area of 11.25×4.0 m^2. Within each main plot and subplot a distance of 2 m and 1m respectively was kept for path. Recommended packages of practices for wheat were adopted for management.

Weekly soil moisture samples were taken during drying cycles by gravimetric method from sowing to harvesting and also before and after each irrigation. Soil samples were taken at 0-15, 15-30, 30-60, 60-90 and 90-120 cm soil depth layers. Canopy temperatures were recorded at weekly intervals during noon hours with the help of teletamp infrared thermometer (Model AG-42). Stomatal resistance and leaf transpiration rates at weekly intervals on



Figs. 1 (a-f). Variation of relative evapotranspiration with : (a-c) leaf water potential, and (d-f) canopy temperature

matured leaves, upper and lower sides both, were recorded with the help of Li-1600 steady state porometer. Predawn leaf water potentials were measured before sunrise with the help of pressure chamber apparatus (PMS Instrument Co.) in all the treatments. The results were analysed by developing response functions between relative evapotranspiration and stress indices in wheat during different stress cycles after applying irrigation in wheat at different phenophases.

3. Results and discussion

3.1. *RET versus predawn leaf water potential*

Figs. 1 (a-c) show the variation of relative evapotranspiration (RET) with predawn leaf water potential for different dates of sowing in wheat. The variation in RET was a complex function in early (D_1) medium (D_2, D_3) and late (D_4, D_5) sown conditions when stress was provided up to anthesis stage [Figs 1 (a & b)], however, after anthesis it was a linearly decreasing function for normal sown dates (D_2-D_4) [Fig. 1(c)]. In early sown conditions the decrease in RET was faster as compared to late sown conditions, where due to slow depletion of soil moisture the available RET was higher for a particular value of predawn leaf water potential. The variation in RET with leaf water potential was not linear in vegetative phase due to differences of available soil water in meeting the atmospheric demand. However, under normal and stress-free conditions, there was a linear decreasing RET response with soil moisture status in different sowing dates. In early sown wheat the depletion of available soil moisture was faster due to the higher evapotranspiration rates in October, whereas in late sown conditions the depletion of soil moisture was slower due to less atmospheric demand. Therefore, due to this imbalance of soil moisture depletion in meeting the external atmospheric demand, the vegetative growth is either retarded or excessive and resulted in complex behaviour of RET variation with predawn leaf water potential. The behaviour of predawn leaf water potential under stress-free conditions [Fig. 1(c)] under normal dates of sowing was linear, but under stress the behaviour of RET shifted towards a functional relationship with predawn leaf water potential. Knowing the atmospheric demand in different climatic conditions with the use of these graphs, we can determine the different levels of leaf water potential to maintain an optimum level of RET so that growth and development of crops is not restricted. Therefore, the leaf water potential behaves as an indicator of internal moisture status of the plant to regulate the RET through atmospheric demand.

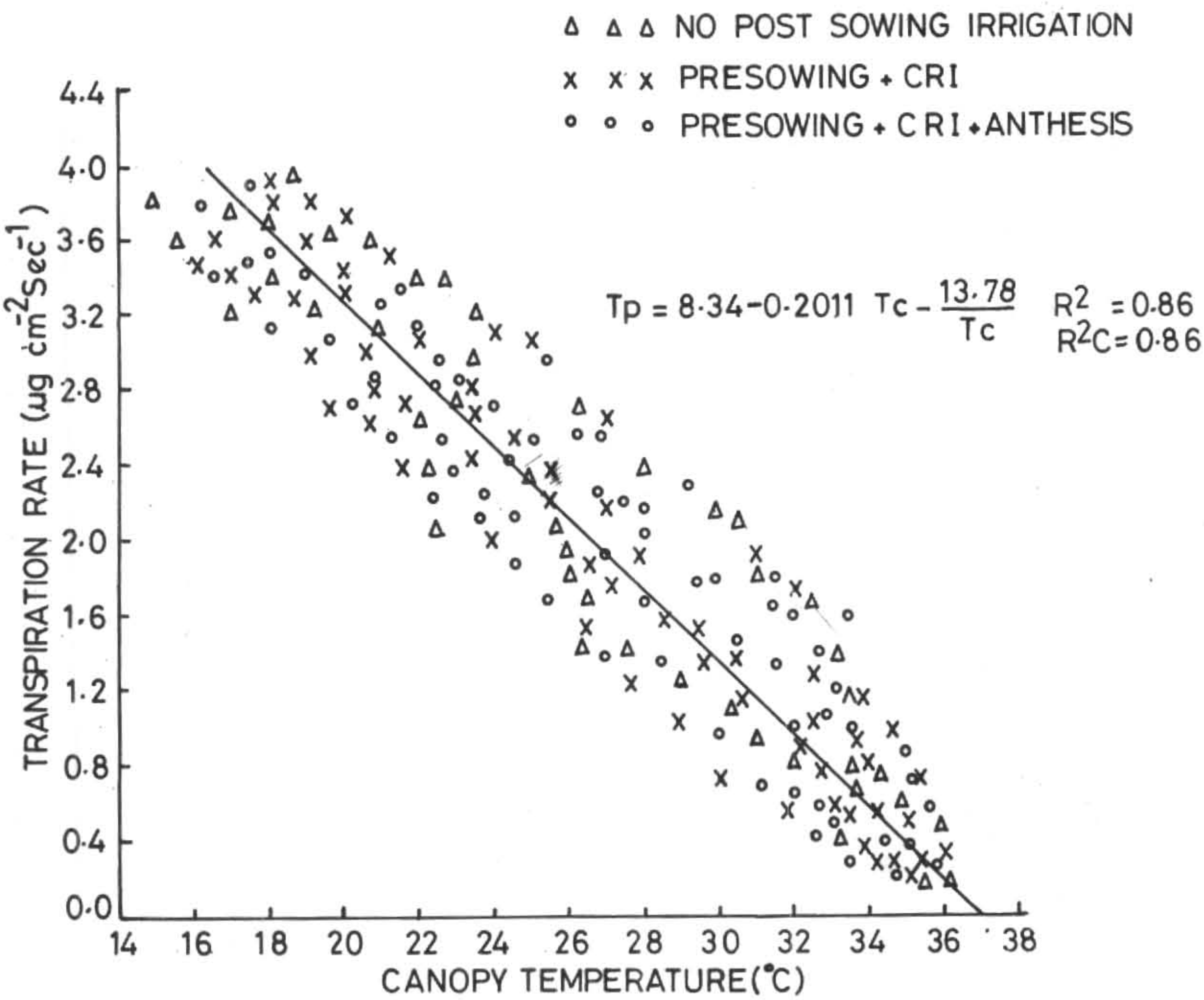
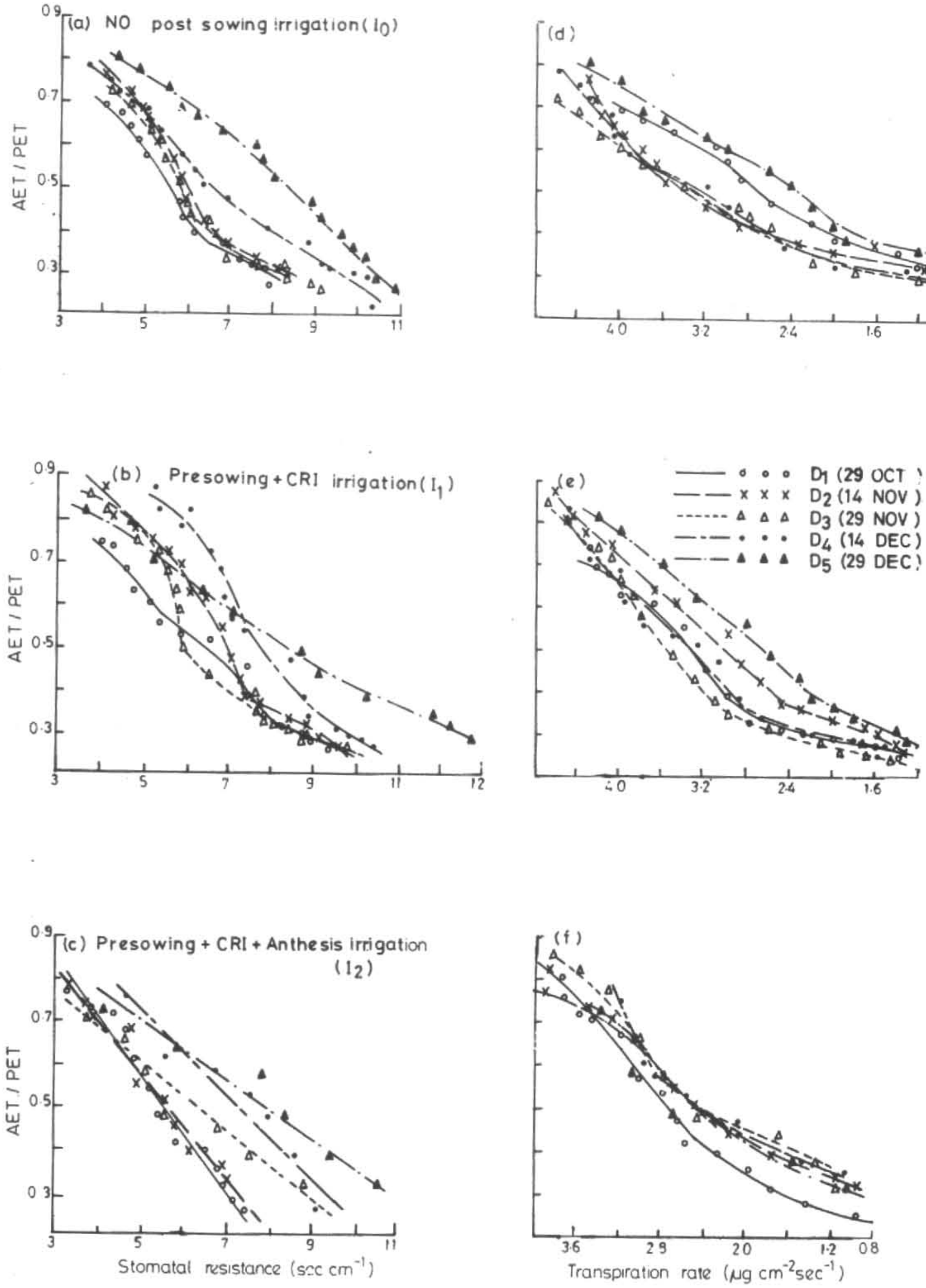


Fig. 2. Variation in transpiration rate with canopy temperature in wheat for different moisture levels

3.2. *RET versus canopy temperature*

The complex behaviour of relative evapotranspiration with canopy temperature for different dates of sowing (D_1-D_5) under different soil moisture stress (I_0, I_1, I_2) conditions is shown in Figs. 1 (d-f). Canopy temperature increased with decrease of RET in all treatments. Canopy temperature was influenced by the transpirational cooling of different plant organs under the atmospheric demand. Canopy temperature had a linear reciprocal decreasing behaviour with the increase in transpiration rate explaining the 86 per cent variation at the point of contact (Fig. 2) and, therefore, the canopy temperature behaves as a useful criteria for scheduling irrigation. It may be noted that to maintain the RET level of 0.5, 0.6, 0.7 and 0.8 it was essential to maintain the canopy temperature of 20, 18, 16 and 15°C respectively in early sown wheat at vegetative phase [Fig. 1 (e)]. As 15-20°C temperature range is best for vegetative development of wheat for higher dry matter production, it would be desirable to maintain the level more than 0.5. However, in the reproductive phenophases a higher canopy temperature of 20° to 25°C is beneficial for better sink development and, therefore, we need to maintain a value of RET of the order of 0.5 to 0.7 at physiological maturity. Therefore, to obtain optimum RET level at different phenophases in wheat, the corresponding canopy temperatures are maintained as a criteria for scheduling irrigation and regulating the available plant soil moisture status.

It was also observed that the scattering of canopy temperature values under different stress treatments of different dates of sowings was more [Figs. 1 (d-f)] as compared to scattering of leaf water potential values [Figs. 1 (a-c)] indicating that the predawn leaf water potential was a better stable parameter for characterising the plant moisture status in comparison to canopy temperature.



Figs. 3 (a-f). Variation of relative evapotranspiration rate with : (a-c) stomatal diffusion resistance, and (d-f) transpiration rate

3.3. *RET versus stomatal resistance*

Figs. 3 (a-c) show the complex behaviour of RET with stomatal resistance for different dates of sowing under different soil moisture conditions. It was observed that the scattering of the diffusive resistance values were much higher [Figs. 3 (a-c)] as compared to the predawn leaf water potential values [Figs. 1 (a-c)] with decrease of RET. Figs. 3 (a & b) show that with the decrease of RET there was increase in stomatal resistance in early and normal sown condition in a complex behaviour and shifted towards a parabolic function during vegetative phase of late sown wheat. During the reproductive phase again the spread in RET with increasing diffusion resistance was higher [Fig. 3 (c)].

On comparing behaviour of leaf water potential [Figs. 1 (a-c)] with the stomatal resistance patterns [Figs. 3 (a-c)] with decreasing trend in RET the predawn leaf water potential behaved as a better stable parameter as it was a direct function of internal plant moisture status in the plant leaves. However, the stomatal resistance behaved as an indirect parameter of plant moisture status because it is a function of leaf water potential and osmotic potential.

3.4. *RET versus transpiration rate*

Figs. 3 (d-f) show the parabolic to complex functional behaviour of transpiration rate with decreasing RET under different dates of sowing in different moisture treatments in wheat even in the reproductive phenophases. However, the scattering of values of transpiration rate [Figs. 3 (d-f)] were also lesser as compared to the scattering in the values of other indices. The transpiration rate being a resultant productive parameter of internal moisture status in the plant under the external atmospheric demand, behaved uniformly in similar manner at different phenophases under stress conditions. Fig. 3 (d) shows that when no irrigation was given at CRI stage the transpiration rate decreased to 0.3. Under stress-free conditions decrease in RET with decreasing transpiration rate was faster in a parabolic pattern [Fig. 3 (f)] as during grain development evapotranspiration was higher. Transpiration rate has been reported by several workers to be strongly related to the wheat yield and yield attribute (Stanhill 1986, Aggarwal *et al.* 1986). Transpiration rate directly functions as a parameter for scheduling irrigation to meet the atmospheric demand. The transpiration rate has been widely exploited to explain the behaviour of crop growth, development and growth of yield attributes and eventually in building the water production function (Hanks 1983).

4. Conclusions

The study has brought out the following results :

(*i*) Stress indices present a complex behaviour in the variation of relative evapotranspiration in wheat at different phenophases with the decreasing soil moisture.

(*ii*) Predawn leaf water potential and transpiration rates were more stable stress indices and can be used for scheduling irrigation, maintenance of growth and development in wheat.

(*iii*) Canopy temperature is also simple and useful stress index for scheduling irrigation.

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