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ESTIMATION OF WATER DEFICIT IN WHEAT USING MICROMETEOROLOGICAL AND SOIL MOISTURE VARIABLES

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ABSTRACT

Water deficit in four wheat (*Triticum aestivum* L.) cultivars (HD 1982, HD 2009, UP 319, and Kalyan Sona) was estimated using micrometeorological (temperature, relative humidity, wind speed, and solar radiation) and soil moisture data. Water deficit could be estimated accurately (R^2 between 0.951 and 0.997) when the differences between cultivars and effect of crop age were assumed significant. But the accuracy decreased when the difference between cultivars only was assumed significant (R^2 0.690 and 0. 849). Accuracy decreased further (R^2 0.264) when the differences between cultivars and effect of crop age were assumed negligible.

INTRODUCTION

Many studies have been made to integrate the plant water status and different climatic and soil moisture variables (Yang and Jong, 1971; Downey, 1972; Frank *et al.*, 1973; Schulze *et al.*, 1973; Hagen and Skidmore, 1974; Reicosky and Lambert, 1978), But integrated approaches that combine the soil, plant, and climatic variables together are few. Water status of plant is a combined manifestation of soil, plant, and climatic variables. Keeping this in view, the present study was undertaken on four cultivars of wheat.

MATERIAL AND METHODS

Site

Field and laboratory studies were conducted during the winter season of 1975-76 at the Experimental Station of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (29°N, 79.30°E, at about 244 metres above mean sea level). The region has a dry season from November through May and a wet or monsoon season from June through October, when about 90 per cent of the average annual precipitation (1400 mm) is received. May and June have high temperatures (29-31°C) and December, January, February are the coolest months (13-16°C).

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Crop and soil

Four adjacent fields, 1.5 ha each, sown with four different cultivars of wheat (*Triticum aestivum* L.) viz., HD 1982, HD 2009, UP 319 and Kalyan Sona, were selected. Except for HD 2009, which was sown in the second week of December, sowing was done between November, 10 and 19, 1975. The crops were for commercial purposes and agronomic practices were adopted alike in all the fields.

The soil type of all the fields was Beni silty clay loam and an imperfectly drained Aquic Hapludoll (Deshpande *et al*, 1971).

Observations

(a) *Schedule*

Observations were recorded from early morning before sunrise to late evening, at three-hour intervals for three days: February 8 and 22, and March 7, 1976. Observations were started after the crop canopy had developed well and had an average height of 30 cm. After March 7, observations were terminated because of the setting of senescence.

(b) *Plant and soil*

Weatherlay's (1950) method was used for relative water content (RWC) of the leaf and water deficit (WD) was derived by subtracting RWC from 100. For each observation, soil and plant samples from each field were collected from three different locations distributed all over the field. Subsequent samplings during the day were done in the vicinity of these initial sampling sites. Soil sampling was always done adjacent to the sampled plant. Soil sample was taken upto 45 cm depth and gravimetric moisture converted to potential value by using moisture desorption curve, developed from pressure plate assembly (Richards, 1948).

(c) *Micrometeorological variables*

Temperature and relative humidity at middle of the crop canopy were recorded at three different locations within a field with the mercury filled glass thermometer and wet and dry bulb thermometers, respectively, placed inside a well perforated white wooden box. Average wind speed at the surface of canopy was monitored with an anemometer (range 1-15 m/sec). Total solar radiation at 122 cm above ground surface was recorded with a pyranometer at the agro-meteorological observatory of the Crop Research Centre.

Analysis

Leaf water deficit was computed by fitting multiple regression with linear parameters on a TDC 12 computer. Water deficit (Y, per cent) was taken as the dependent variable and temperature (x_1,°C), humidity (x_2, per cent), wind speed (x_3, m/sec), solar radiation (x_4, ly/min), and soil water potential (x_5, -bar) as the dependent variables. X_0 was dummy independent variable. The general form of the equation is

$$Y = ax_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$$

Water deficit was computed with the following assumptions: (i) there is a significant difference between the cultivars to develop water deficit and the effect of crop age on development of water deficit is also significant, (ii) there is a significant difference between the cultivars to develop water deficit but the effect of crop age on development of water deficit is negligible, and (iii) there is a negligible difference between the cultivars to develop water deficit and the effect of crop age on development of water deficit is also negligible.

With the first assumption, an equation was developed for each cultivar on each date. With second assumption, equation was developed for only cultivars and for this, observations of all the three days for individual cultivar were pooled together. With third assumption, data for all the cultivars and dates were pooled together to develop a single equation.

RESULTS AND DISCUSSION

Micrometeorological and soil moisture variables

Micrometeorological and soil moisture conditions on different days are shown in Figs. 1 to 3. Micrometeorological variables, in general, followed the established pattern, and hence, their general distribution is not discussed. The weather conditions may modify the general pattern of distribution (Luff, 1965; Reicosky and Lambert, 1978). On March 7 due to cloud covers maximum radiation was received around 1500 hours. The moisture conditions shown in the figures do not represent change over time but were the average moisture value in the zone where the plants sampled for water deficit were growing. During a day negligible change in soil moisture potential in a field is expected.

Water deficit

Water deficit followed the same pattern as was observed for the micrometeorological variables. It increased from morning uptill around 1300 hr and then the recovery started. Similar trends for leaf water potential have been reported earlier (Ackley, 1954; Cowan, 1965; Ritchie, 1974).

The water deficits estimated following first assumption i.e. significant difference between the cultivars to develop water deficit and a significant effect of crop age on the development of water deficit were close (R^2 0.951 to 0.99) to observed values (Figs. 1 to 3). Thus Micrometeorological and soil moisture variables had together

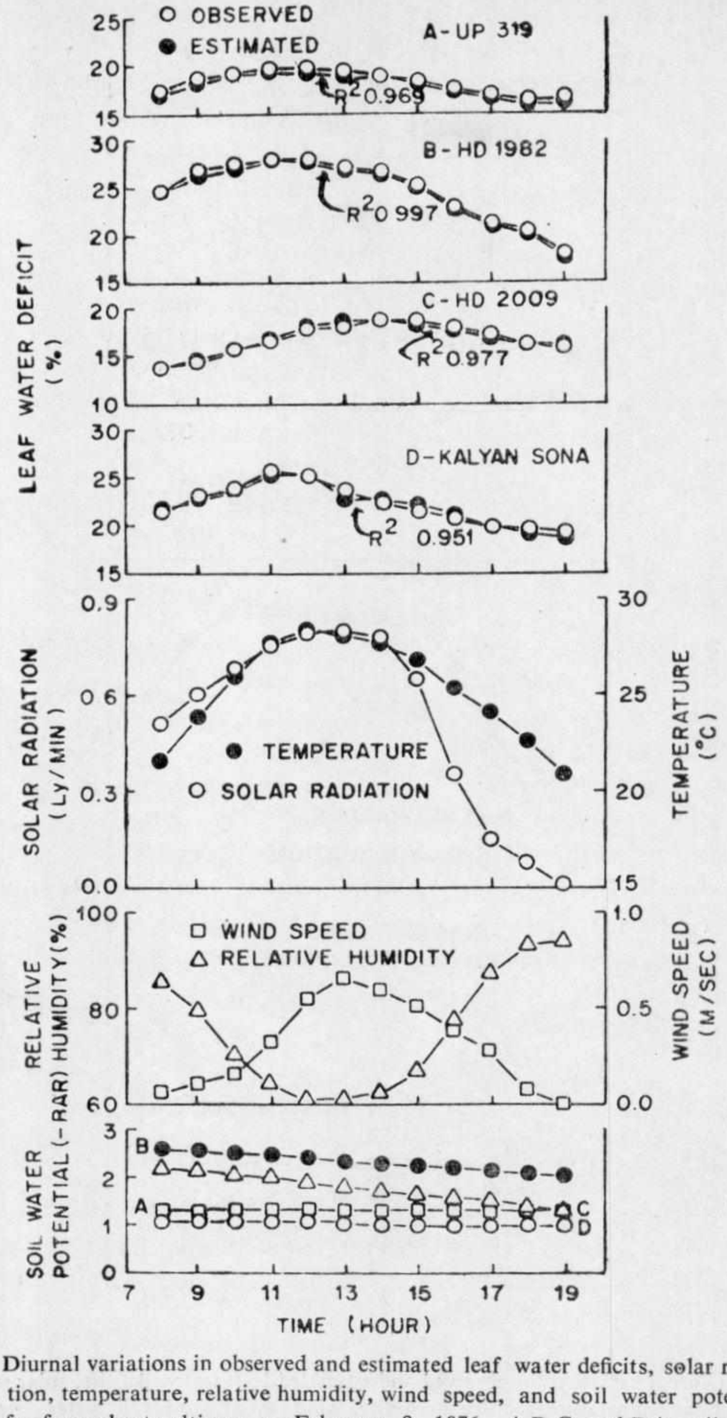


Fig. 1 Diurnal variations in observed and estimated leaf water deficits, solar radiation, temperature, relative humidity, wind speed, and soil water potential for four wheat cultivars on February 8, 1976. A,B,C, and D in soil water potential curves denote water potential for the fields sown with cultivars UP 319, HD 1982, HD 2009, and Kalyan Sona, respectively.

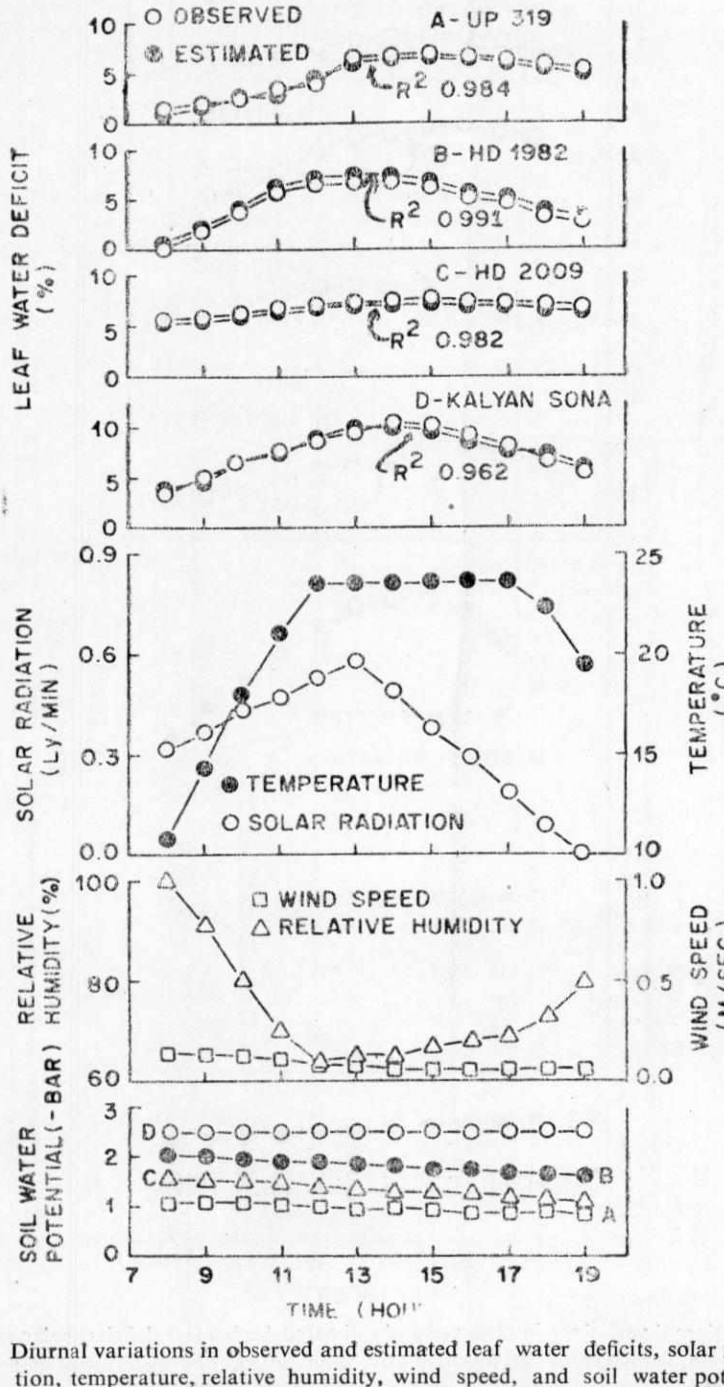


Fig. 2 Diurnal variations in observed and estimated leaf water deficits, solar radiation, temperature, relative humidity, wind speed, and soil water potential for four wheat cultivars on February 22, 1976. A,B,C, and D in soil water potential curves denote water potential for the fi elds sown with cultivars UP 319, HD 1982, HD 2009, and Kalyan Sona, respectively.

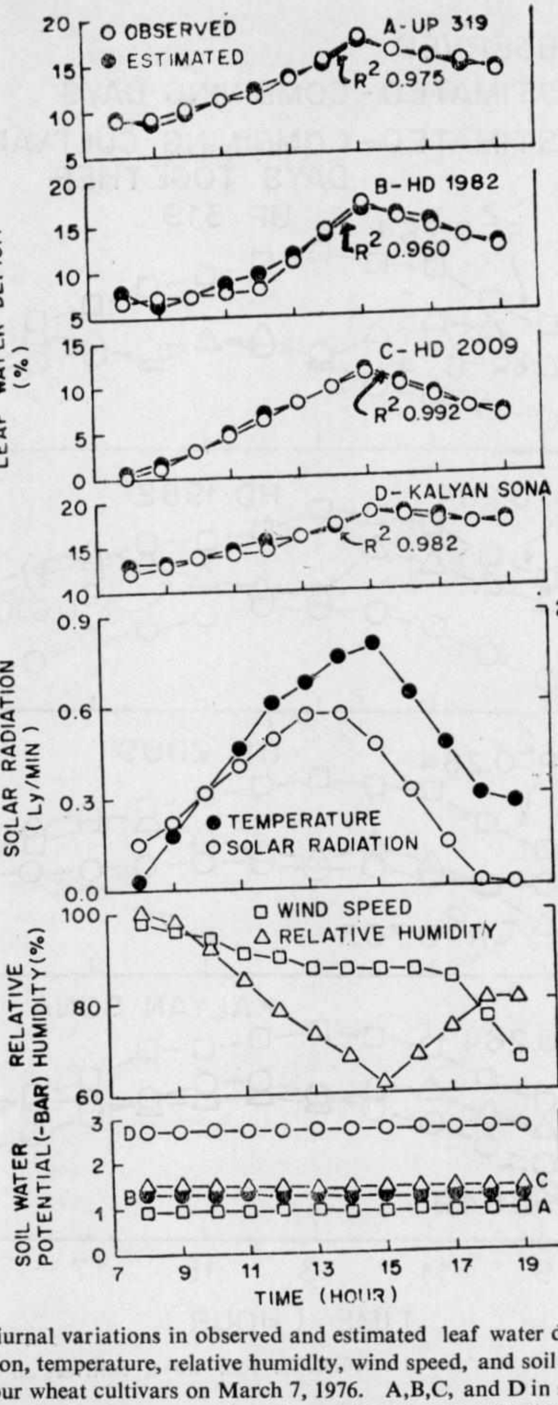
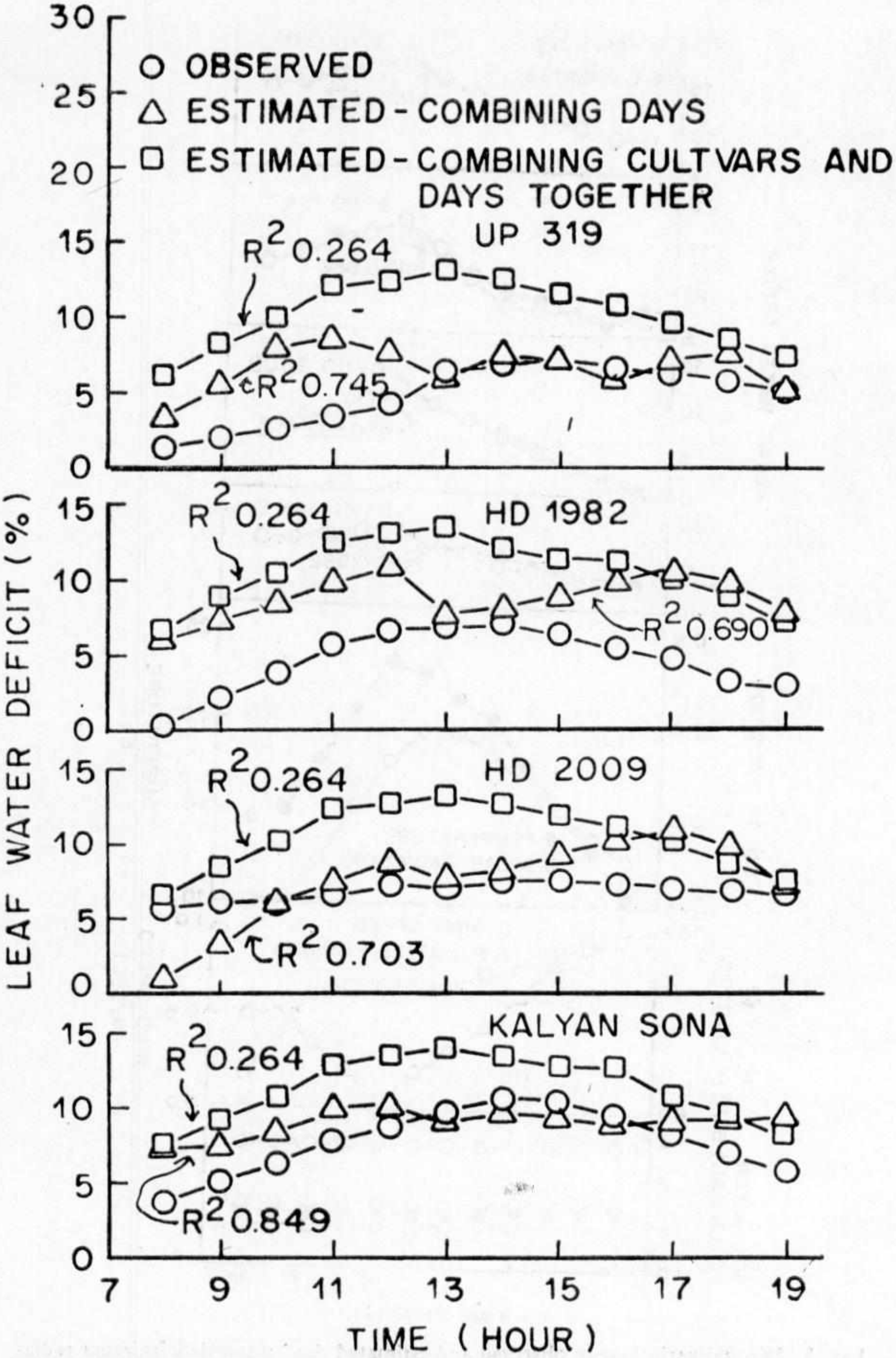


Fig. 3 Diurnal variations in observed and estimated leaf water deficits, solar radiation, temperature, relative humidlty, wind speed, and soil water potential for four wheat cultivars on March 7, 1976. A,B,C, and D in soil water potential for the fields sown with cultivars UP 319, HD 1982, HD 2009, and Kalyan Sona, respectively.



Fig, 4 Observed and estimated water deficits for four wheat cultivars on February 8, 1976.

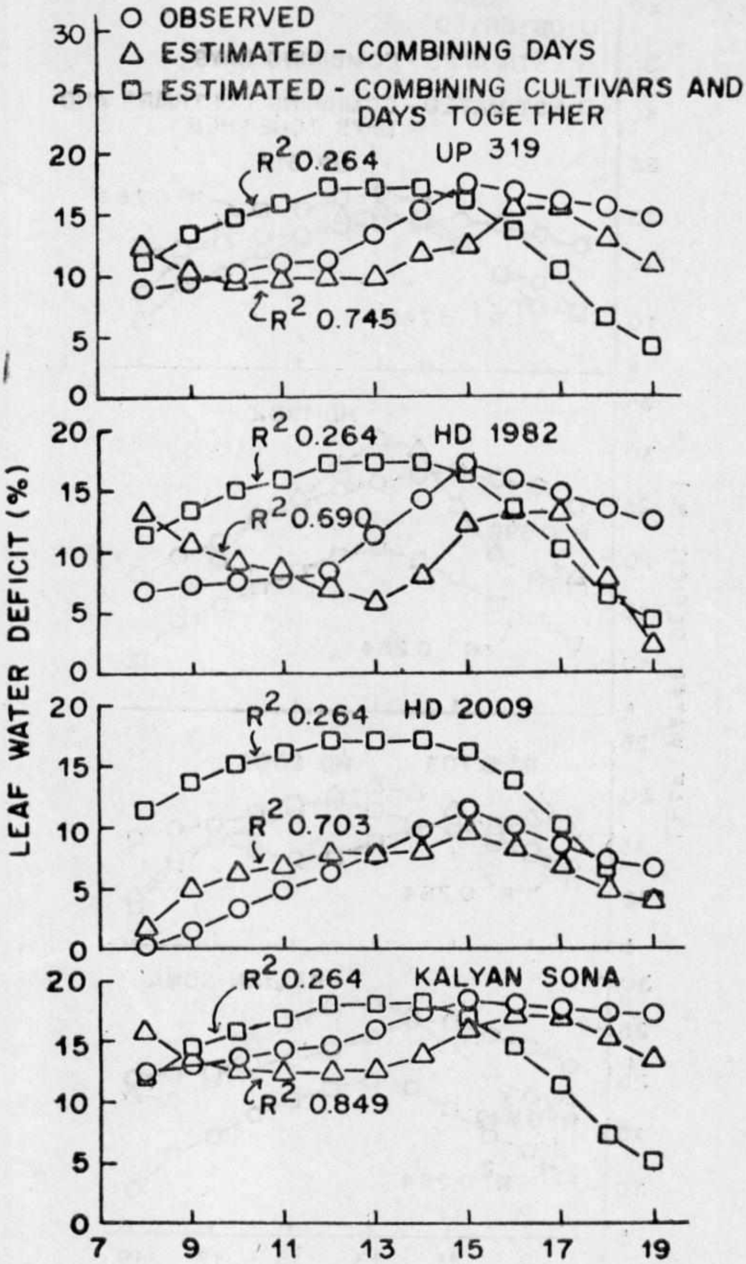


Fig. 5 Observed and estimated water deficits for four wheat cultivars on February 22, 1976.

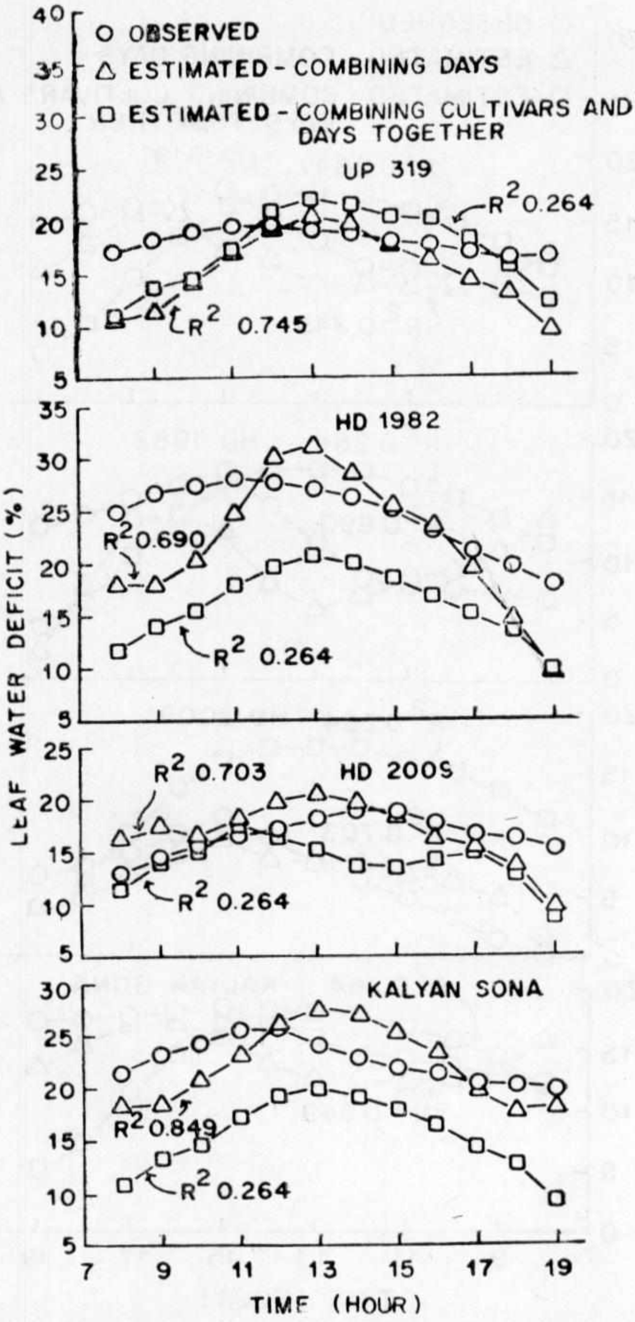


Fig. 6 Observed and estimated water deficits for four wheat cultivars on March 7, 1976.

accounted for at least 95 per cent of the water deficit. The results also indicated that with advancement of age some other crop factors like degree of senescence etc. affected water deficit, but their effects appeared to be very small.

The efficiency of estimation decreased when crop age (R^2 0.690 to 0.849) and crop age and cultivars were combined together (R^2 0.264), respectively (Figs. 4 to 6). These results indicate that the cultivars did not respond uniformly to climatic and soil moisture changes. To illustrate the nature of equations under three assumptions, a few selected equations are given in table 1.

Table 1. Multiple regression equations for quantifying water deficit in wheat with micrometeorological and soil moisture variables in wheat.

Cultivar	Equation	R^2
Assumption :	Significant cultivar difference and crop-age effect	
February 8, 1976		
UP 319	$Y^* = -27.067 + 0.567\ x_1 + 0.303\ x_2 - 94.821\ x_3 + 8.218\ x_4 + 3.245 x_5$	0.984
February 22, 1976		
	$Y = 52.856 - 0.315\ x_1 - 0.349\ x_2 + 1.871\ x_3 - 3.783\ x_4 - 6.708\ x_5$	0.975
March 7, 1976		
	$Y = 1.836 + 0.237\ x_1 - 0.046\ x_2\ 2.872\ x_3 + 1.256\ x_4 + 11.286\ x_5$	
Assumption :	Significant cultivar difference only	
	$Y = 19.736 - 0.400\ x_1 - 0.478\ x_2 + 13.511\ x_3 - 17.566\ x_4 + 36.266\ x_5$	0.745
Assumption	No cultivar difference and no crop-age effect	
	$Y = -35.208 + 1.170\ x_1 + 0.255\ x_2 + 7.707\ x^3 + 5.324\ x_4 + 0.552\ x_5$	0.264

* Y, x_1 through x_5 denote leaf water deficit %, temperature °C, relative humidity %, wind speed m/sec, solar radiation ly/min, and soil moisture potential-bar, respectively.

CONCLUSION

Water deficit for various cultivars of wheat could be quantified with the environmental and soil moisture variables. The accuracy for the individual cultivars, however, decreased when estimation was attempted on a long term basis. A single equation usable for all the cultivars and throughout the season had a very low accuracy.

REFERENCES

Ackley, W.B. 1954. Seasonal and diurnal changes in the water contents and water deficits of Barlett Pear leaves. *Plant Physiol.* 29 : 445-448.

Cowan, I.R. 1965. Transport of water in the soil-plant-atmosphere system. *J. Appl. Ecol.* 2 : 221-239.

Deshpande, S.B., Fehrenbacher, J.B. and Beavers, A.H. 1971. Mollisols of Tarai region of Uttar Pradesh, Northern India. II. Genesis and classification. *Geoderma* 6 : 195-201.

Downey, L.A. 1972. Response of relative water content in *Zea mays* L. to changes of potential in the rhizosphere and atmosphere. *Agric. Met.* 10 : 137-140.

Frank, A.B., Power, J.F. and Willis, W.O. 1973. Effect of temperature and plant water stress on photosynthesis, diffusion resistance and leaf water potential in spring wheat. *Agron. J.* 65 : 777-781.

Hagen, L.J. and Skidmore, E.L. 1974. Reducing turbulent transfer to increased water-use efficiency. *Agric. Met.* 14 : 153-168.

Luff, M.L. 1965. The morphology and microclimate of Dactylis-Glomerata Tussocks. *Journal of Ecology* 53 : 771-787.

Reicosky, D.C. and Lambert, J.R. 1978. Field measured and simulated corn leaf water potential. *Proc. Soil Sci. Soc. Amer.* 42 : 221-228.

Richards, L.A. 1948. Porous plate apparatus for measuring moisture retention and transmission by soil. *Soil. Sci.* 66 : 105-110.

Ritchie, J.T. 1974. Atmospheric and soil water influences on the plant water balance. *Agric. Met.* 14 : 183-198.

Schulze, E.D., Lange, O.L., Kappen, L., Buschbom, U. and Evenari, M. 1973. Stomatal responses to changes in temperature at increasing water stress. *Planta.* 110 : 29-42.

Weatherlay, P.E. 1950. Studies in the water relations of the cotton plant. I. The field measurement of water deficits in leaves. *New Phytol.* 40 : 81-97.

Yang, S.J. and Jong, E. de. 1971. Diurnal fluctuation and relative magnitude of water potential in wheat tissue. *Canadian J. of Plant Science.* 51 : 333-336.