

Diurnal variation in energy balance components of dryland wheat*

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ABSTRACT

In this study, the energy balance components were worked out for different phases of the crop growth. Relationship between the plant height and dry matter, the plant height and leaf area index (LAI) and biomass use efficiency have been determined and discussed. The diurnal energy pattern has also been studied. The analysis revealed that the plant growth is maximum between jointing and flowering stages. The plant height bears a positive highly significant correlation with LAI before senescence sets in. The water use efficiency ranges from 2 to 7 gram of dry matter per kg. of water use. Maximum water loss appears to take-place during jointing stage. Maximum radiation energy occurs at about 1300 hrs. While latent heat flux maxima is seen an hour later.

Keywords : Jointing, senescence, sensible heat, soil heat flux

The net radiation energy through interaction with physiological processes in plant growth, exerts a profound influence on bio-mass production. The bio-mass is also affected by micro-climatic conditions. In India very little agrometeorological experimental work particularly on its micrometeorological aspects seems to have been undertaken except those by Bhan *et al.*, (1990), Chowdhury *et al.*, (1992), Gaonkar and Tripankar (1993). Rosenberg and Verma (1978) reported significant contribution of sensible heat advection during an extended drought at Nebraska and found

that half of the energy for ET was supplied by sensible heat advection. Aese and Siddoway (1982) showed various energy balance components in semi-arid climate for wheat crop and found strong influence of sensible heat on evapotranspiration. Brun *et al.*, (1985) calculated energy balance for spring wheat based on water availability. Such information is useful for better understanding of how the wheat plant responds to changing environmental conditions and to moisture stress. This knowledge can help in adopting appropriate strategies for optimising

* Paper presented in the national seminar on " Agrometeorological Research for Sustainable Agricultural Production" held at GAU, Anand during 27-28 Sept. 2001

wheat production and water use efficiency.

The purpose of this study is to demonstrate the extent of influence of micro-climate and soil factors on evapotranspiration and other components of energy balance on wheat crop in a dryland zone. This has been done for Pune located in Deccan plateau – a typical dryland area in the country.

MATERIALS AND METHODS

The experiment was conducted in a field of 7.2 ha during the *rabi* crop season of 1991-92 on vertisol clayey soil at Agricultural College, Pune. The soil had a field capacity of 39.5 % and permanent wilting point 23.2%.

HD 2187 variety of wheat was sown 22.5 cm apart on 27.11.91. The row-to-row distance was 30 cm. The crop was harvested on 30.3.92. Four irrigations were given to the crop during emergence, tillering, jointing and soft dough stages on 17.12.91, 8.1.92, 27.1.92 and 16.2.92 respectively. The plants in the entire filed area were uniformly fertilised with 60: 40: 0 kg ha⁻¹, N-P-K.

Net radiation was measured with net pyradiometer mounted 1 m above the crop canopy positioned at mid way in a plant row. Soil heat flux was measured

with soil heat flux plates buried 5 cm below the soil surface in the field. Water use was measured as depletion of soil moisture in a 60 cm soil profile during a seven day interval by using the following equation (Islam 1991).

$$ET = 10 H \sigma (S_0 - S_1) + I + P$$

Where

ET = Evapotranspirative loss (cm) in a week

H = Soil depth assumed as 0.6 m

σ = Bulk density of the soil (g cm⁻³)

S₀ = Soil moisture content in the beginning of the week

S₁ = Soil moisture at the end of the week

P = Precipitation during the week (mm)

I = Irrigation supplied (mm)

Incoming radiation was measured with Eppley pyranometer. The leaf area index (LAI) was measured every week by leaf area meter. Biometric observations like plant height, number of tillers per plant, number of leaves and dry bio-matter were measured every week through standard sampling technique described in Agrimet Technical Circular No.50 of India Met. Dept.

The weather remained generally dry during the crop season. On 26.12.91

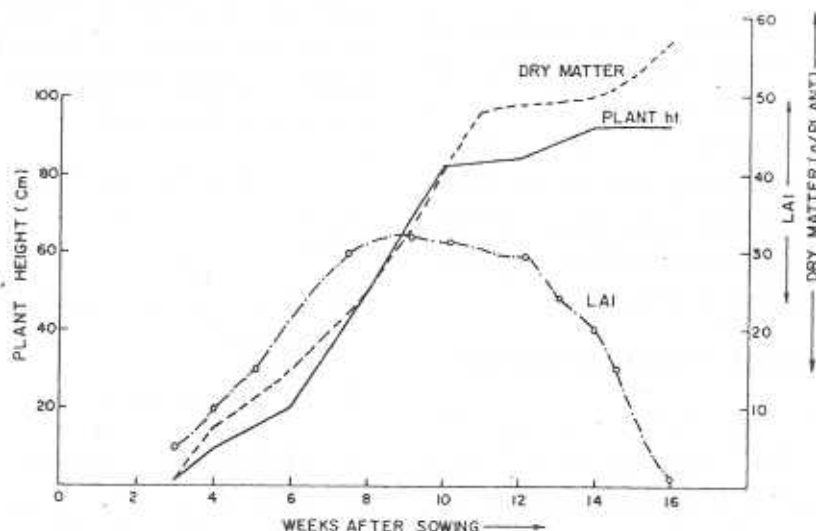


Fig. 1 : Weekly variation of plant height (cm), dry matter (kg ha^{-1}) and leaf area index (LAI)

at crown root initiation (CRI) stage, the sky was almost cloudy and on 15.1.92 at jointing stage, it was partially so. Temperatures were measured through Assman Psychrometer at 3 hourly intervals within the crop canopy throughout the crop season.

RESULTS AND DISCUSSION

Plant height and dry matter

Plant height is an important factor, as it determines the zero plane displacement and the thickness of the boundary layer. The plant height was 18.0 cm at tillering stage and increased to 40.5 cm at jointing with a faster

increase from jointing to flowering (81.5 cm). At soft dough stage, it attained a maximum height of 90.5 cm (Fig. 1).

Rapid increase in dry matter was observed from jointing to soft dough stage by which time the plants produced 95 % of total dry matter. The contribution of dry matter production from flowering stage onwards was mainly due to earhead development. The correlation coefficient between plant height and dry bio-produce (0.93) was naturally very high.

Plant height and leaf area index

As the plant grows, the crop canopy

Table 1: Water use efficiency ($\text{kg ha}^{-1}\text{mm}^{-1}$) in different stages

Growth stage	Days after sowing	Cumulative ET (mm)	Dry matter (kg ha^{-1})	WUE
Crown root initiation	28	17.6	1150	65.3
Tillering	42	58.7	2720	46.3
Jointing	49	90.9	6350	69.9
Flowering	70	202.4	9380	46.3
Soft dough	84	286.9	11800	41.1
Hard dough	105	378.6	11940	31.5
Maturity	119	416.3	12170	29.2

and hence the LAI increases. The increase in LAI during early crop growth period which is useful in utilizing radiant energy more effectively continues upto anthesis period. LAI then gradually diminishes as a sequel to plant senescence. The crop attained 65% of LAI at tillering stage. Maximum LAI of 3.4 was attained during next 6-7 weeks. The plant had maximum green leaves of nearly 21 at jointing stage.

Correlation between the plant height and LAI upto anthesis was found as 0.95. LAI and dry matter upto green vegetative phase were highly correlated (0.98).

Biomass-water use efficiency

The water use efficiency (WUE) was calculated as the ratio of dry matter produced above the ground surface to the total amount of water consumed.

Water use was estimated by gravimetric method following the change in the profile of soil water content to a depth of 60 cm at regular weekly intervals.

WUE is highest ($69.9 \text{ kg ha}^{-1}\text{mm}^{-1}$) during anthesis period (Table 1) and decreased later for the rest of the crop season.

Energy balance components

The mean daily values of the energy balance in different stages of growth are given in Table 2. Net radiant energy, R_n was found to vary from stage to stage. Maximum value of R_n i.e., 139.81 Wm^{-2} per day is seen during jointing stage. Largest absolute value of latent heat flux, LE is also seen during jointing and it exceeds R_n by slightly more than 2%. LE continues to be higher than R_n upto flowering stage when the former is 8.9 % higher than the latter. For the

Table 2 : Mean daily energy balance components (Wm^{-2}) in different phases

Growth phase	R_n	LE	G	H
Emergence	133.4	-96.1	-17.8	-19.5
Crown root initiation	116.1	-96.4	-15.8	-3.8
Tillering	113.2	-107.3	-11.7	5.8
Jointing	139.8	-145.4	-9.0	14.6
Flowering	117.7	-130.9	-8.1	21.1
Soft dough	128.2	-127.9	-8.3	7.8
Hard dough	129.7	-110.2	-12.9	-6.5
Maturity	148.6	-75.6	-18.1	-54.8

season as a whole LE is found as 889.8 Wm^{-2} slightly less than the net radiant energy. High values of LE in the post flowering stage has also been reported by Johnson *et al.* (1981).

The soil heat flux is found always directed away from the surface in all phenological phases with higher values at emergence, crown root initiation and at senescence. The sensible heat was high at jointing and flowering stages when LE was also high. (21.1 Wm^{-2} at flowering followed by 14.6 Wm^{-2} at jointing stage which is nearly 1/6th and 1/10th of R_n respectively) indicating advecting conditions.

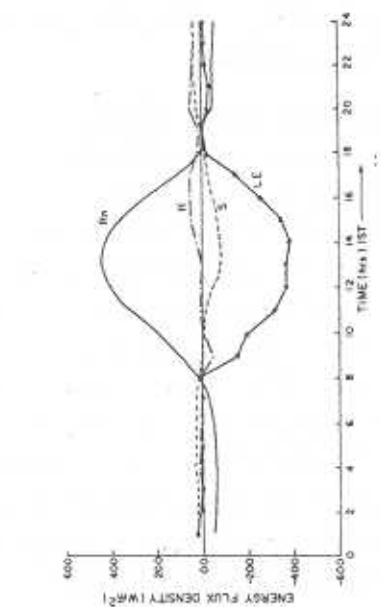
Diurnal pattern of energy balance components

Typical diurnal pattern of energy balance components each for the four

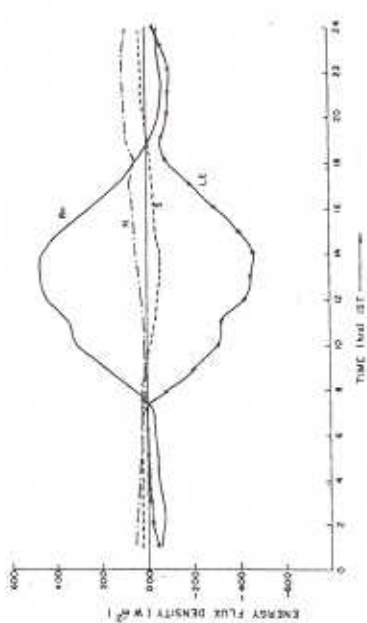
growth phases viz., germination, tillering, flowering and maturity is shown in Fig.2.

Germination phase: At the germination stage air temperature during the mid-day ranged from 27.2 to 32.2°C, vapour pressure deficit (VPD) from 17.9 to 27.5 kPa and mid-day wind speed varied from 4.5 to 6.6 ms⁻¹. R_n showed a typical single peaked pattern with positive values from 0730 to 1730 hrs and negative during the rest of period (Fig 2a). Maximum R_n at about 1300 hrs. Was 510 Wm^{-2} . Soil heat flux, and sensible heat flux, H were directed towards the surface between 1700 to 0800 hrs. and 1615 to 0700 hrs. respectively.

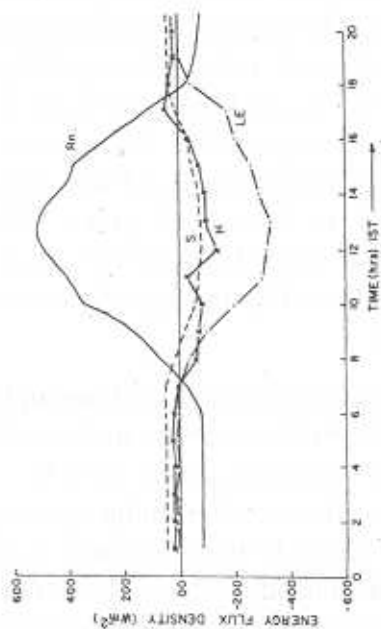
During nearly mid-day (i.e. 1200-1300 hrs), 63% of R_n was utilised in evaporation, 19% by sensible heat and



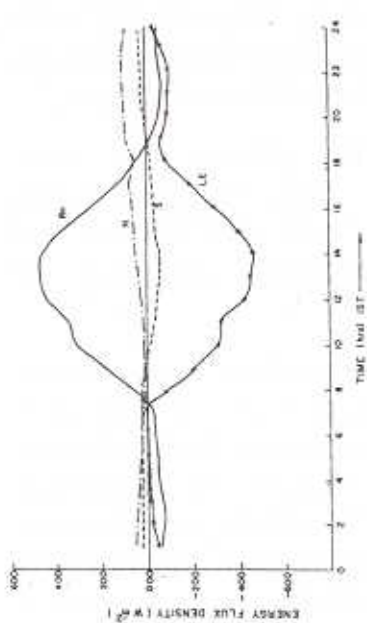
(a) Germination 4.12.91



(b) Tillering 6.1.92



(c) Flowering 7.2.92



(d) Maturity 8.3.92

Fig. 2 : Diurnal pattern of energy balance components

18% by soil heat fluxes at this stage. The pattern of energy balance components in other stages resembled generally that in germination with minor changes.

Tillering phase: The noon temperature during this phase varied from 24.8 to 31.6°C, the VPD from 14.0 to 22.3 kPa and surface wind speed from 5.0 to 7.6 ms⁻¹.

With the gradual decrease in solar angle consequent to the apparent movement of the sun to the southern hemisphere after winter equinox, a decrease in R_n (with largest value equal to 440 Wm⁻²) is seen (Fig 2b) during middle of tillering phase occurring at 1300 hrs. There is a lag of nearly one hour for LE to attain largest value of 380 Wm⁻². The soil heat flux has a smaller component directed towards soil surface from about 1900 to 1000 hrs and a comparatively larger component away from it with lowest value of -80 Wm⁻² occurring in the day time.

During mid day nearly 86% of R_n was utilised by the plant for evapotranspiration and the rest for the heating the soil. Large values of soil heat flux is not unusual in tropical areas during afternoon hrs. Mokate (1992) found that between 1200 to 1400 hrs, soil heat flux as large as 14% of R_n during jointing stage of wheat at Pune. Kim *et al.*, (1989) also observed in NE

and east central great plains of USA, nearly 15% of R_n is utilised as soil heat flux by winter wheat.

Flowering stage: Nearly 60% of the flowering was over at this time (Fig 2c) The mid-day temperature varied from 29 to 32.6°C and VPD from 18.7 to 24.8 kPa. Because of setting up of convection currents, noon time was quite windy with surface wind speed ranged from 4.8 to 7.2 ms⁻¹. Peak R_n of 510 Wm⁻² occurred at 1300 hrs while that in LE (of 530 Wm⁻²), an hour later indicating advective conditions. Even after sunset, significant LE seems to have been lost to the atmosphere.

Pattern of diurnal variations of energy components at maturity is shown in Fig. 2d. Mean mid-day temperature, VPD and wind velocity ranged from 35.9 to 38.7°C, 29.4 to 45.4 kPa and 3.5 to 5.5 ms⁻¹ respectively. As in case of flowering, maximum R_n of 450 Wm⁻² occurred an hour after noon. The maximum amplitude of LE nearly equalled that of R_n and was observed at 1400 hrs.

From morning hours till late night, H was directed towards the surface with highest value of about 100 Wm⁻² experienced towards evening. In other words, sensible heat appears to be advected from adjoining fields towards the experimental site. The soil heat flux

is negative between 1000 to 1800 hrs and is either zero or directed towards the surface during rest of the period, with peak of 60 Wm^{-2} occurring at 1400 hrs.

ACKNOWLEDGEMENT

The authors are grateful to Dr. R. R. Kelkar, Director General of Meteorology, New Delhi for giving permission and also like to thank Shri. S. K. Banerjee DDGM (Agrimet) for his encouragement in preparing the paper.

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