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MICROMETEOROLOGICAL PROFILING OF PEARL MILLET UNDER RAINFED CONDITIONS ACROSS VARYING GROWING ENVIRONMENTS

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SUMMARY

The main aim of this research work was to assess-profile micrometeorological conditions in rainfed Pearl millet under varying growing environments in semi-arid region of Hisar, Micrometeorological observation was measured at three phenophases (Tillering, Flag leaf and 50% flowering) at hourly interval when attained the particular phenophases (decided on the basis of visual observation) by used of Point quantum sensor, pyranometer with digital multivolmeter, radiometer, soil heat flux plat and Asman Psychrometer. The upward and radiation fluxes are measure of energy available at the crop canopy. The energy balance components namely net radiation (Rn), latent heat flux/vaporization (LE), Sensible heat flux (A), and soil heat flux (G) reached the peak value at sun overhead or noon and important of these were fundamental quantity of energy available to drive the crop physiological process. Day time the energy flow results in the warming of pearmillet leaf and within canopy air and crop surface quite cooling as outside soil surface. The percentage of net energy utilized to the various components varies from pearmillet tillering to 50% growth stage growth stages. Radiation use efficiency among the cultivars sown during 2nd fortnight of June appeared to be at par with national check variety i.e. GHB 558 exhibiting surface remittance and varietal characteristics. Absorption of radiation was increase from tillering to 50% flowering under different growing environments. Decreased the utilization of LE in-advancement growth upto 50 % flowering but in late sown D_2 followed the D_3 crop will utilized higher. An average transmission higher at 50% flowering might be due to panicle erected vertically and leaves are bending toward the stem with the minimized angle. The vertical PAR for favorable microclimatic profile patterns in pearl millet crop was observed in 2nd fortnight of June sown. Thus, the higher grain yield was attained with efficient utilization of micrometeorological variables during the course of the experiment year.

Key words: Weather relations, PAR, Energy balance, Latent heat flux, radiation component, microclimate

Microclimatic conditions of temperature, humidity, wind, dew, frost, heat balance and evaporation in the immediate vicinity of the crops are very important, as they regulate and determine the physiological responses of the plant. The microclimatic conditions *i.e.* canopy temperature, air-canopy temperature difference, actual evapotranspiration; photosynthesis rates, assimilation and transpiration rate of crop are also responsible for the daily physical and physiological process influencing the final yield.

Crop management practices especially sowing time, planting method, irrigation management, row spacing, intercropping, mulch application, shelter belts, etc. also affect the microclimatic environment *viz*, canopy temperature (Tc), wind speed (WS), light interception, soil moisture and rate of water loss etc. Pearl millet being a C_4 crop, has higher radiation use efficiency (RUE) and high photosynthetic efficacy, especially under high temperature due to low photorespiration. Radiant energy can be manipulated within a crop field through adoption of crop stand geometry *viz*., row spacing and orientation. Ashraf *et al*., (2001) reported that soil moisture had a significant effect on net photosynthetic rate (PN), transpiration rate, stomatal conductance, and water use efficiency in pearl millet lines. While studying impact of low PAR in rice, Auffhammer *et al*. (2006) estimated that the reduction in PAR availability reduces rice yield. Stanhill and Cohen (2001) suggested that plants would be insensitive to changes in solar radiation at high light, but since plant canopies usually consist of several leaf layers, in which radiation decreases exponentially from layer to layer, low light levels at which photosynthesis is light limited are common in crop canopies, hence, decreased solar radiation might reduce the productivity. Mani *et al*., (2015) while studying thermal stress management strategies in wheat under late sown conditions reported higher radiation use efficiency (RUE) under pre-sowing treatment when overnight soaked seed sowing with 25 per cent higher seed rate in dry bed followed by irrigation at milking. Biomass and yield differences in sunflower due to variations in temperature and CO_2 concentration were also reported by Jyothi Lakshmi *et al.* (2017). Das *et al.* (2020) reported that eCO_2 and temperature levels favored cell elongation which consequently resulted in taller plants in sun flower. The sowing time significantly influence crop growth parameters like plant height, flag leaf area, number of tillers, and yield attributes like ear head length and 1,000 grain weight, and maximum values were noted with growing environment time on 15th March (Upadhyay *et al*., 2001; Deshmukh *et al.* (2013)). Choudhary *et al.* (2014) reported that the planting density was different in term of PAR interception by moong bean crop. The crop which was sown widely intercepted 12 per cent less radiation than the crop which was sown densely. Lack of favourable climatic elements leads to disturbance in plant's physiological and energy exchange processes which results in decreased crop productivity. Hence, under such circumstances anticipating climatic variability and change, there is urgent need to modify microclimatic conditions so as to mitigate the impact of climate change on crop production more so in rainfed regions. Therefore, present study of micrometeorological profiling in pearl millet was envisaged under varying growing environments.

MATERIALS AND METHODS

Experimental details: The field experiments were carried out during *kharif* seasons of 2017 and 2018 at research farm of Dept of Agril Meteorology, CCS HAU Hisar, India situated at 29° 10' N latitude; 75° 46' E longitude and 215.2 m amsl altitude. The crop was sown with three dates (main treatment) *viz*., D_1: 2nd Fortnight of June, D_2: 1st Fortnight of July and D_3: 2nd Fortnight of July having three varieties (sub treatment) viz., V_1: GHB-558 (National check), V_2: HHB 67 (improved) and V_3: HHB-272. The experiment was laid out in split-plot design having gross plot size of 4.0 x 3.6 m and net plot size of 3.0 x 2.6 m with four replications.

Micrometeorological profile study in rainfed pearmillet experiment

Micrometeorological observation was measured (in crop season kharif 2017 & 2018) at three phenophases (Tillering, Flag leaf and 50% flowering) from 0900 to 1600 hr. at hourly interval when attained the visual phenophases, through using the pyranometer with digital multivolmeter, radiometer, soil heat flux plat and Asman Psychrometer. The energy balance components namely net radiation (Rn), latent heat flux/vaporization (LE), Sensible heat flux (A) and soil heat flux (G) reached the peak value at sun overhead or noon. The observations on vertical canopy PAR pattern (with positioning the point quantum sensor on top, middle and bottom) at tillering, flag leaf and 50 % flowering phenophase. The observations on air and canopy temperature (°C) using Infrared (IR) thermometer; wind speed (m sec^{-1}) using digital potable anemometer; RH (%) using digital psychrometer and chlorophyll index using chlorophyll meter were measured.

Solar radiation components in rainfed pearmillet

The amount of solar radiation received by crop was measured with the help of pyranometer connected to a digital multivoltmeter. The measurements were made at above crop. While making measurements the pyranometer was kept horizontally so as to follows the cosine law. Soil heat flux: Soil heat flux was measured with the help of soil heat flux plate which were kept at 5 cm soil depth in cropped field and connected to a digital multivoltmeter (Medoes and Co., Australia).

Calculation of energy balance in rainfed pearmillet

The energy balance evaluated over the pearmillet crop is given the following equation:

$$Rn = G + A + LE + M_i \qquad ...(a)$$

Where, Rn = Net radiation (MJm^{-2} day^{-1}), G = Soil heat flux (MJm^{-2} day^{-1}), A = Sensible heat (MJm^{-2} day^{-1}), LE = Latent heat of vapour flux (MJm^{-2} day^{-1}) and Mi = Miscellaneous energy used in physiological processes of plant, MJm^{-2} day^{-1} (This parameter is generally neglected under pearmillet rainfed crop condition because of it had low value of less than 1%). The latent heat flux was calculated using the following formula:

$$LE = (R_n - G)/ (1 + \beta) \quad ...(b)$$

Where, β is Bowen ratio and is inferred from the measurements of dry and wet bulb temperature at three heights (top, middle & bottom) and is represented as below:

$\beta = 0.66 \times d_t/d_e$ (Denmead and Mclory, 1970)

Where, d_t=Temperature gradient between two heights, de = Vapour pressure gradient between two heights. The sensible heat flux (A) was calculated from the energy balance equation using measured R_n & G and calculated LE values as given

$$A = R_n - G - LE \quad ...(c)$$

The derived equation for wave length (µm) emitted by rainfed crop under field condition were evaluated using Stefen Boltzman Constant Law and Wien's Displacement Law. Zero plane displacement values were calculated using the formula of Z_0=2h/3. The trend analysis of micrometeorological profiling in respective treatments and further impact assessment on yield attributes and final yield was undertaken. RUE for biomass is computed from weekly interval i.e. 14 to 63 DAS and at harvest under respective growing environment. The accumulated radiation components net radiation also evaluated by using the numerical formula, which given below.

Computation of different variable using the equation

The seven weather parameters as T_{max}, T_{min}, T_{mean}, RH_m, RH_e, BSS/n, WS (u_2), Cloud condition. The accumulated radiation component computed and tabulated under rainfed condition grown crop, from emergence to physiological maturity of crop. The Latitude, Altitude was used to compute each parameter required for the radiation components.

Step 1:

a. Calculation of Angle of Declination (δ)

$\delta = 0.4102\sin\left(\frac{2\pi}{365}(J-80)\right)$ Where declination is in radians ...(i)

b. Convert Latitude to Radians (ϕ)

$\phi = \left(latitude * \frac{\pi}{180}\right)$, Where latitude is in decimal degrees ...(ii)

c. Estimating potential extraterrestrial radiation (R_a)

$R_a = \frac{118}{\pi}\left\{\cos^{-1}(-\tan\delta\tan\phi)\sin\phi\sin\delta + \cos\phi\cos\delta\sin\left[\cos^{-1}(-\tan\delta\tan\phi)\right]\right\}$ ...(iii)

Where, R_a is in MJ m^{-2} day^{-1}

Step 2: Estimate Net Radiation (R_{net})

a. Estimating downward solar (short wave) radiation (R_s)

This is the Hargreaves (1998) radiation formula.

R_s = 0.16 * R_a * sqrt[(T_{max} - T_{min})], Where R_s & R_a are in MJ m^{-2} day^{-1} ….(iv)

In equation daily observed maximum (T_{max}) and minimum temperature (T_{min}) were used

The PAR values were converted into MJm^{-2}, daily IPAR was calculated using expression.

PAR = Rs x 0.48 (Oleson *et al.*, 2000)

b. Estimating atmospheric emissivity (ε_a)

The original equation has been modified below to suit the units of the database

ε= (0.72+0.005Tmean)(1–0.0084Cloud)+0.0084Cloud …(v)

T_{mean} is mean temperature and cloud cover used for the computation

c. Estimating net long wave radiation (R_L)

Assumed terrestrial emissivity=0.97

R_L = (4.903*10^{-9}) * (ε_a - 0.97) * [T_{mean}+273]^4 ...(vi)

Where, R_L is in MJ m^{-2} day^{-1}

d. Estimating net radiation (R_{net})

R_{net} = (0.77 * R_s) - R_L, Where R_L, R_{net}, R_L are in MJ m^{-2} day^{-1} … (vii)

RESULTS AND DISCUSSION

Prevailing weather variables during crop growing period

The mean weekly temperature *viz.* T_{max} and Tmin (Fig 1) varied between 32.5 to 36.8°C and 18.3

to 27.9°C, respectively. The averaged weekly relative humidity values varied between 75 to 93 per cent (morning time) and 29 to 81 per cent (evening time) and a larger fluctuation was observed in the evening time relative humidity (Fig. 1). The ideal temperature for pearl millet crop growth under the rain-fed conditions varied between 24.3 to 33.6 °C. The temperature range of 32.4 to 35.0 °C observed during crop vegetative phase had optimized effect on the length of crop growth cycle. The temperature fluctuations within the range of 1.5 to 3.2 °C favoured grain filling period, if otherwise explained the reduced productivity (Fig. 1). The main reason to temperature fluctuation in after noon might be attributed to prevailing higher temperature of 37.8 °C. The higher air temperature induced ambient heating may increase the water loss from stomata. The amount of rainfall during *kharif* seasons of 2017 and 2018 was 201 and 259 mm, respectively having averaged rainfall of 230 mm (Fig. 1). During both the kharif seasons, the rainfall was received well within 11 rainy days at par with the normal rainy days during the growing period. The percentage coefficient of variation value was 21.2 among rainy days especially during vegetative stage to panicle initiation stage caused variable relationship in crop sown during second fortnight of June and first fortnight of July.

Grain and biological yield

The pearl millet crop sown during 2nd fortnight of June, had better growing environment with favorable micrometeorological conditions throughout thus performed well under semi-arid rain-fed climatic conditions of Hisar, Haryana (Table 1). Similar on the pattern, national check (GHB-558) performed well over local university release (HHBs) varieties. The crop management practices for altering micrometeorological conditions favoring growth and development of these local varieties need to be explored for optimum and potential yield of pearl millet under growing environments (Table 1).

Cchlorophyll index in pearl millet

Chlorophyll index in pearl millet crop increased gradually up to 49 days after sowing and decreased thereafter (Table 2) owing to age of leaves toward maturity with decreased green pigment/yellowing of leaves. A drastic reduction in chlorophyll index was observed nearly at maturity i.e. 63 days after sowing under different sowings and varieties of pearl millet. Chlorophyll content in the pearlmillet was higher in D_1 among other treatments. Chlorophyll content increased gradually upto 49 DAS and decreased at crop maturity

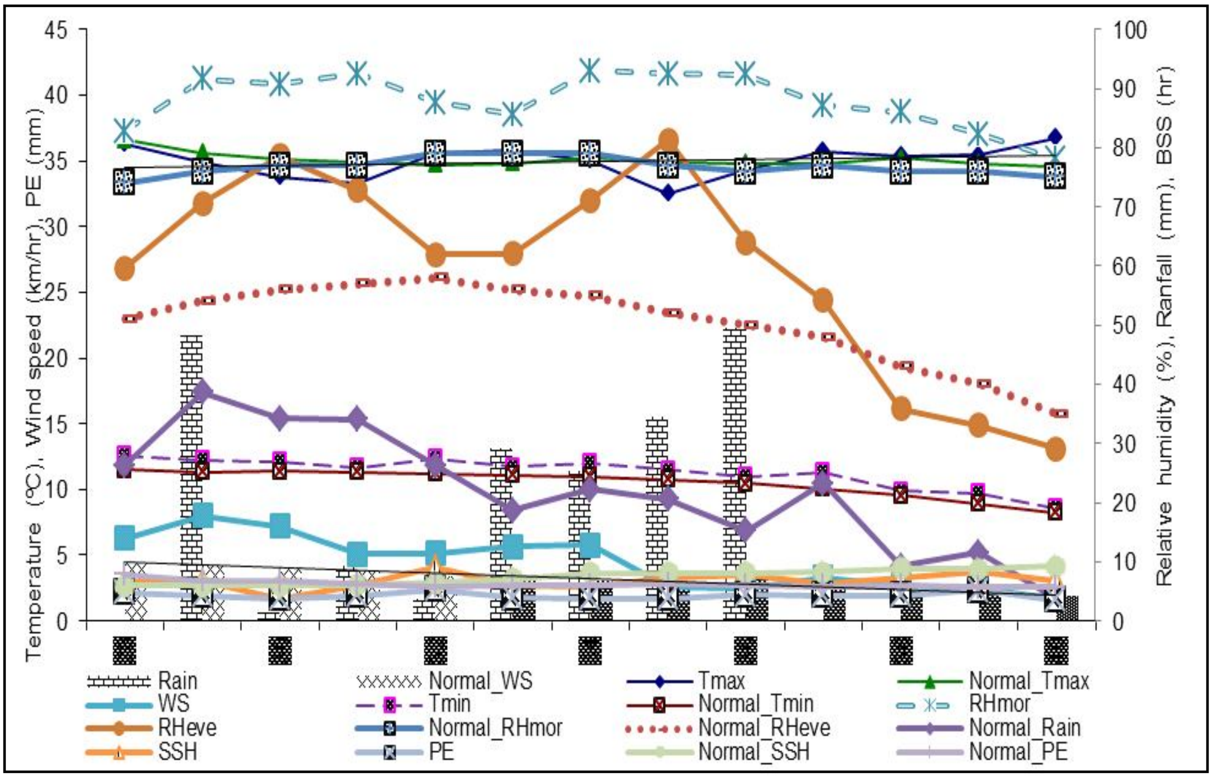

Fig. 1. Prevailing weather conditions alongwith normal parameters on weekly basis during crop growing period.

TABLE 1

Yields of pearl millet under different growing environments

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)
D_1 (2nd Fortnight of June)	3240.6	10703.5	13944.1
D_2 (1st Fortnight of July)	3092.6	10055.6	13148.2
D_3 (2nd Fortnight of July)	2981.3	9777.4	12758.7
CD at 5% level	89.1	105.6	196.7
V_1 - GHB-558 (National Check)	3296.5	10518.3	13814.8
V2 -HHB 67 (improved)	2925.8	9481.3	12407.1
V_3 - HHB-272	3018.0	9907.2	12925.2
CD at 5% level	75.6	189.4	266.1

(63 DAS) phase among all the treatments during both the crop seasons. Among different growing environments, the highest chlorophyll content was recorded in D_1 followed by D_2 and D_3. In the rainfed pearmillet to attained the 49 DAS was highest the chlorophyll contents and then decreasing, so similarly its might be impact on photosynthesis process and assimilation rate further change the micrometeorological condition to the leaf (Table 2).

Radiation and radiation use efficiency in pearl millet

Radiation is the difference between total upward and downward radiation over the rainfed pearmillet. Downwards radiation (as transmitted & reflected) fluxes were varies with development of phenophases. The quantification of radiation use efficiency (RUE) is important for determination of yield potential of a cultivar in a particular growing environment. The RUE was higher (>0.50) 49 days after sowing (around peak vegetative stage) onwards in all the sowings environment and till the physiological maturity (upto 63 days after sowing) due to higher biomass accumulation. Among the growing environments, crop sown during 2nd Fortnight of June) better utilized radiation (RUE range 0.54 to 0.78 $gm^{-2}MJ^{-1}$) for biomass production than the crops sown later in the month of July (Table 3).

While observing vertical canopy PAR pattern the variation was 2.0-5.0 $MJm^{-2}day^{-1}$. Further, decreasing trend was observed from vegetative phase onwards till the grain filling stage owing to higher leaf cover of ground and more absorption per cent of PAR. The consumption of PAR and associated parameters *viz.*, bright sun shine hours-sun light and assimilation rate were optimum in second fortnight of June sown pearl millet crop. Thus, it may hereby be ascertained that the microclimate profile pattern was optimum and favorable enough in June sown pearl millet crop consequently produced higher grain yield by utilizing microclimatic variables efficiently during the growing period. The radiation components were numerically calculated with the using equation i to vii. The net radiation and its components were evaluated and quantified on average basis during the crop growing periods (Table 4). The intercepted PAR (IPAR) varied between 198 to 268 $MJm^{-2}day^{-1}$ and increased progressively with delay in crop sowing until July, because of availability if more sun light / increased sun shine hours on clear sky days. The computed wavelength ranged between 8.89 to 9.64 µm (long wave) at all the growing stages of crop calculated on the basis of soil temperature values.

Radiation characteristics over rainfed Pearmillet

The visual phenophases observation was observed at appearing Tillering, Flag leaf and 50%

TABLE 2

Chlorophyll index in pearl millet under various growing environments

Treatments	Days After Sowing (DAS)							
	14	21	28	35	42	49	56	63
Main Plots								
D_1 (2nd Fortnight of June)	13.5	14.2	21.2	35.3	53.1	61.2	48.3	31.3
D_2 (1st Fortnight of July)	9.4	24.1	30.4	57.3	62.2	54.1	44.6	28.3
D_3 (2nd Fortnight of July)	18.1	20.6	43.0	59.8	42.0	40.9	26.4	17.8
CD @ 5% level	2.2	2.8	4.2	2.1	13.4	5.1	2.1	6.9
Sub Plots								
V_1 – GHB 558 (National Check)	13.2	19.9	29.3	44.2	46.7	55.3	43.2	26.8
V_2 – HHB 67 (improved)	14.2	20.0	33.5	56.0	52.6	46.5	34.2	26.8
V_3 – HHB 272	13.7	19.0	32.1	52.6	58.0	54.1	41.8	25.8
CD @ 5% level	NS	NS	0.3	3.4	4.1	0.2	1.1	NS

TABLE 3
RUE (#$gm^{-2}MJ^{-1}$) under varying growing environments in pearl millet

Treatments	Days After Sowing (DAS)								
	14	21	28	35	42	49	56	63	At harvest
Main Plots									
D_1 (2nd Fortnight of June)	0.04	0.13	0.20	0.41	0.54	0.60	0.63	0.78	0.67
D_2 (1st Fortnight of July)	0.04	0.13	0.16	0.30	0.42	0.48	0.53	0.61	0.53
D_3 (2nd Fortnight of July)	0.04	0.13	0.14	0.28	0.41	0.50	0.49	0.57	0.50
Mean	0.04	0.13	0.17	0.33	0.45	0.53	0.55	0.65	0.57
SD	0.01	0.01	0.03	0.07	0.08	0.07	0.07	0.11	0.09
CV %	9.30	1.40	19.80	22.53	16.95	12.90	13.40	16.92	16.31
Sub Plots									
V_1 – GHB 558 (NC)	0.03	0.12	0.14	0.33	0.46	0.56	0.58	0.79	0.66
V_2 – HHB 67 (improved)	0.04	0.13	0.17	0.37	0.43	0.49	0.51	0.56	0.50
V_3 – HHB 272	0.05	0.14	0.20	0.28	0.47	0.52	0.57	0.61	0.54
Mean	0.04	0.13	0.17	0.33	0.45	0.53	0.55	0.65	0.57
SD	0.01	0.01	0.03	0.04	0.02	0.03	0.04	0.13	0.08
CV %	20.30	6.24	15.93	13.46	4.21	6.19	7.22	19.33	14.92

Biomass weight in gram per meter square.

TABLE 4
Effect of different radiation (PAR: $MJm^{-2}day^{-1}$) characteristics in Pearmillet under varying growing environments

Growing Environments	PAR: $MJm^{-2}day^{-1}$							
	Tillering							
	2017				2018			
	Rs	A	T	R	Rs	A	T	R
D_1	24.9	4.0	17.4	2.5	12.43	1.99	8.82	1.24
D_2	17.6	2.8	13.0	1.8	12.36	2.04	9.08	1.23
D_3	9.4	1.5	0.2	1.1	16.50	2.72	0.44	2.01
Flag Lead								
D_1	24.5	3.9	17.2	2.4	17.7	2.8	12.4	1.8
D_2	15.4	2.5	11.4	1.5	13.2	2.1	9.8	1.3
D_3	16.3	4.2	10.4	1.6	14.1	3.7	9.0	1.4
50% Flowering								
D_1	23.6	6.2	15.9	1.7	25.6	7.0	17.3	2.0
D_2	24.5	6.5	16.6	1.7	21.0	5.8	14.2	1.7
D_3	23.9	6.3	16.1	1.7	23.7	6.5	16.0	1.9

PAR- photosynthetically active radiations, A: Absorbed PAR, R- reflected PAR, T- transmitted PAR.

flowering. Absorption of PAR radiation were increase from the tillering to 50% flowering in all their growing environment. The absorption of PAR radiation was at par in the both crop year at 50 % flowering, respectively but higher at 50%flowering. The utilization of PAR radiation was varying over different growth stage as absorption, Transmission (middle) and reflection i.e. at bottom of crop canopy (Table 4). PAR transmitted ($MJm^{-2}day^{-1}$) at bottom near soil surface, soil heat flux and temperature, thermal conductivity pattern had decreasing trend from vegetative stage onward till grain filling stage because of more leaf area cover percent absorption of PAR thereof. The intercepted photosynthetic active radiation upto flag leaf stage was at par when compared with other phenophases, thereafter with further advancement of phenophases at 50 per cent flowering onwards.

Energy balance component over rainfed Pearmillet

The diurnal pattern of energy balance components was studied at three growth stage i.e. Tillering, Flag leaf and 50% flowering. The energy balance components namely net radiation (R_n), latent heat flux/vaporization (LE), Sensible heat flux (A) and soil heat flux (G). The LE values were slightly higher in D_1 at Tillering, Flag leaf and 50% flowering followed D_2 and D_3 respectively. The results revealed that variation in the energy utilized at three stages in the 2017 under D_1 as LE: 5.81 to 7.95 (around 63 to 74 %), A: 0.74 to 2.37 (19 to 22 %) and G: 0.14 to 24 $MJm^{-2}day^{-1}$ (3 to 4%) of the net radiation. At a par results were revealed in kharif 2018 in the three energy components utilized (Table 5). At the 50% flowering stage the pearmillet crop were evaluated the less energy utilized in the ground heat energy. The moderated value of sensible heat components which were favoured the phenophase as growth and development through utilized essential energy to requisite the profile (inside crop) air temperature. The lower value of soil heat flux at 50% flowering in the respective growing environments (Table 5) in the rainfed pearmillet cropped field might be due to the only small amount as fraction of net radiation reached up to soil surface. The percentage of net energy utilized to the various components varies from pearmillet tillering to 50% growth stage growth stages. The absorption of radiation was increase from tillering to 50% flowering under different growing environments. The decreased in utilization of LE under the progression & advancement of growth upto 50 % flowering. An average transmission higher at 50% flowering might be due to panicle erected vertically and leaves are bending toward the stem with the minimized angle.

Zero plane displacement over pearl millet crop

Consistent variability in airflow was observed while evaluating wind/microclimate profile in pearl millet crop (Table 7). The averaged displacement varied were between 79 to 128 cm at initial vegetative stage i.e. 14 DAS to physiological maturity (PM) stage, respectively with maxima reaching at physiological maturity. The coefficient of variation ranged between 10.3 to 17.4 percent with higher variation at early stage 14 DAS and lower variation lower at maturity sate owing to lesser resistance at initial stage of crop growth and vice versa.

Relationship of micrometeorological variables and yields

Various correlation analyses were performed to evaluate the relationship between selected micrometeorological parameters and yield (grain and biological yield) of pearl millet (Table 8). Most of weather variables had positive correlations except wind speed and thermal conductivity with yields of pearl millet. The zero-plane displacement had significant relation with both the yields (grain and biological yield) with coefficient of determination ($r^2 = 0.91$) and (r^2=0.94) with grain and biological yield of pearl millet,

TABLE 5
Energy balance components at three phenophases in Pearmillet under varying growing environments

Growing Environments	Energy balance components: $MJm^{-2}day^{-1}$							
	Tillering							
	2017				2018			
	Rn	LE	A	G	Rn	LE	A	G
D_1	9.94	7.30	2.07	0.38	18.4	13.7	3.6	0.8
D_2	3.57	2.62	0.74	0.14	12.4	9.2	2.4	0.5
D_3	9.40	6.95	1.96	0.36	8.1	6.0	1.6	0.3
Flag Lead								
D_1	10.68	7.95	2.32	2.4	3.9	2.89	0.84	0.15
D_2	9.40	6.97	2.10	1.5	12.0	8.87	2.67	0.43
D_3	7.13	5.29	1.43	1.6	11.9	8.84	2.38	0.60
50% Flowering								
D_1	7.95	5.81	1.65	1.71	12.8	9.4	2.7	0.6
D_2	11.37	8.32	2.37	1.67	2.8	2.1	0.6	0.1
D_3	9.70	7.10	2.02	1.63	9.8	7.2	2.0	0.4

TABLE 6

Accumulated radiation ($MJm^{-2}day^{-1}$) and its components in various growing environments of pearl millet (whole crop duration)

Treatments	Net Short-Wave Radiation (SWRnet)	Net Long Wave Radiation (LWRnet)	Net Radiation (Rnet)	Intercepted PAR (IPAR)
D_1 (2^{nd} Fortnight of June)	329	109	214	198
D_2 (1^{st} Fortnight of July)	348	124	223	212
D_3 (2^{nd} Fortnight of July)	441	225	215	268
Mean	372	156	221	228

TABLE 7

Averaged zero-plane displacement (cm) under growing environments of pearl millet

Dates of Sowing	Days After Sowing (DAS)				
	15	30	45	60	Physiological Maturity
D1 (2nd Fortnight of June)	24	57	111	128	128
D2 (1st Fortnight of July)	21	46	90	119	115
D3 (2nd Fortnight of July)	17	41	81	105	103
Mean	21	48	94	118	115
SD	3.6	8.2	15.4	12.1	12.5
CV%	17.4	17.2	16.4	10.3	10.9

TABLE 8

Relationship of weather variables and grain/biological yield of rain-fed pearl millet

Weather Variables	Seed yield (Kg/ha)	Biological yield (Kg/ha)
Tmax (°C)	0.54	0.54
Tmin (°C)	0.91*	0.14
RHm (%)	-0.03	-0.23
RHe (%)	0.45	-0.40
Wind speed (km/hr.)	0.09	-0.80
Zero plane displacement (cm)	0.91*	0.94*
Thermal conductively (MJm^{-2}°k-day^{-1})	-0.53	-0.46
IPAR ($MJm^{-2}day^{-1}$)	0.39	0.61
Sunshine hour (hr/day^{-1})	-0.16	0.84*
Pan evaporation (mm)	-0.03	-0.80
Rainfall (mm)	0.67	0.09

*Level of significant at 5%.

respectively. Variables *viz.*, minimum temperature (r^2=0.91) and bright sun shine hours (r^2=0.84) too had significant positive relationship.

CONCLUSION

On the basis of experimental study and results obtained, it may be concluded herein that the higher air temperature induced ambient heating of microclimate may increase the water loss from stomata in pear millet leaves. Transmitted PAR at bottom near soil surface, soil heat flux and temperature, thermal conductivity pattern had decreasing trend from vegetative stage onward till grain filling stage because of more leaf area cover and more absorption of PAR. Percentage of net energy utilized to the various components varies from pearmillet tillering to 50% growth stage growth stages. Absorption of PAR-radiation was increase from tillering to 50% flowering under different growing environments. Among the growing environments, crop sown during second fortnight of June better utilized radiation for biomass production than the crops sown later in the month of July. Most of weather variables had positive correlations except wind speed and thermal conductivity with yields of pearl millet.

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