

Prediction of the Total Biomass and Yield of Pearl Millet using Solar Radiation and Spectral Measurements

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Abstract Multiple linear regression models were developed for prediction of pearl millet dry biomass and yield under agroclimatic conditions of Delhi. A stepwise regression analysis was carried out to select the best agrometeorological (absorbed photosynthetically active radiation, evapotranspiration and thermal interaction rate) and spectral indices (infra red/red ratio and normalised difference) which explained maximum variation in dry biomass and yield. The R^2 values obtained were 0.973 and 0.995 for dry biomass and yield models, respectively.

Key words linear, regression, biomass, photosynthetically active radiation, evapotranspiration, thermal, interception, spectral, agrometeorological, infrared, normalised

There are very few studies on the influence of agrometeorological parameters on pearl millet biomass and yield. A direct relationship between evapotranspiration and biomass was found for wheat by Doyle & Fisher (1979) and Chakravarty & Sastry (1983). Ong & Monteith (1984) and Jarwal & Singh (1990) reported direct relationship between biomass production and light interception in pearl millet. Significant correlation existed between infrared/red ratio (IR/R) and normalised difference (ND) with dry biomass in wheat (Das *et al.* 1992). Grain yield was linearly correlated to radiance ratio IR/R and normalised difference during active vegetative period of wheat (Mahey *et al.* 1990). Singh & Singh (1988) developed multiple regression yield model based on weather parameters for cotton. Therefore, this study was undertaken to develop multiple linear regression model for prediction of dry biomass and yield based on agrometeorological and spectral indices of pearl millet crop.

Materials and Methods

Two field experiments with three pearl millet varieties were conducted at Indian Agricultural Research Institute, New Delhi, during *kharif* seasons of 1992 and 1993. The pearl millet varieties PUSA-23, HHB-60 and HHB-67 were sown in east-west and north-south rows in factorial randomized block design with three replications.

All agronomic practices were followed as per recommended package of practices by the Institute. Crop was rainfed during both the seasons (season rainfall : 518.4 in 1992; 519.2 mm in 1993). Final biomass produced and grain yield were recorded at harvest in each plot.

The daily meteorological data were recorded at the observatory on north side of the experimental field. Using these data, the following agrometeorological indices were calculated;

$$\text{Thermal time (GDD)} = T_{\text{mean}} - T_b \dots(1)$$

where,

$$\begin{aligned} T_{\text{mean}} &= \text{mean air temperature in } ^\circ\text{C} \\ T_b &= \text{base temperature } 10^\circ\text{C} \\ &\text{(Ong 1983)} \end{aligned}$$

Heliothermal units (HTU)

$$= (T_{\text{mean}} - T_b) D \dots(2)$$

where,

D = bright sunshine hours

Thermal interception rate (TIR)

$$= S_i/n (T_{\text{mean}} - T_b) \dots(3)$$

where,

S_i = photosynthetically active radiation incident on the canopy, $\text{MJ m}^{-2} \text{day}^{-1}$

n = number of plants $\text{m}^{-2} = 15$

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Table 1 Simple regression analysis between dry biomass, yield of pearl millet and agrometeorological variables and vegetation indices

Parameters	Linear regression analysis					
	Dry biomass (kg ha ⁻¹)			Grain yield (kg ha ⁻¹)		
	a	b	r	a	b	r
GDD	4852.0	4.47	0.74*	1249.0	1.28	0.77*
HTU	6284.0	0.55	0.87*	1730.0	0.15	0.85*
TIR	3515.0	10.52	0.92*	942.0	2.90	0.92*
APAR	7129.0	1.203	0.95*	2125.0	2.71	0.78*
ET	2921.0	23.69	0.91*	8070.0	6.44	0.90*
IR/R (anthesis)	5340.0	573.29	0.58	2781.0	19.23	0.27
ND (anthesis)	-20098.0	37609.8	0.95*	-2009.0	60.435	0.56
IR/R (milking)	1245.0	1820.5	0.74*	1350	305.8	0.45
ND (milking)	-43542.0	78686.0	0.95*	-9543	1800.0	0.79*

* Significant at 5 per cent level of significance

a = Constant

b = Regression coefficient

r = Correlation coefficient

The spectral reflectance was measured by portable spectroradiometer (LI-1800) during 12.00 to 13.00 hours over the crop canopy. The reflectance values within range of 600-700 nm equivalent to MSS red band and 800-1000 nm equivalent to MSS infrared bands were utilized to calculate spectral indices.

$$\text{Infra-red/red ratio} = \frac{\text{Near infra red (IR)}}{\text{Red(R)}} \dots (4)$$

$$\text{Normalised difference} = \frac{\text{IR} - \text{R}}{\text{IR} + \text{R}} \dots (5)$$

Simple linear and multiple regressions were developed between agrometeorological, spectral indices and dry biomass, yield using the statistical technique developed by Fisher (1924). The absorbed photosynthetically active radiations (APAR) were calculated as per the procedure adopted by Rosenthal & Gerik (1991). Evapotranspiration (ET) was calculated using the Penman combination method (Rao 1992).

Results and Discussion

The data were pooled for both *kharif* seasons and a stepwise regression analysis was carried out to select the best agrometeorological and spectral indices for prediction of dry matter and yield.

For stepwise regression analysis, the parameters which showed significant correlation with dry matter and yield were selected. The equations obtained with highest R² values were selected for prediction purpose. The simple regression and correlation coefficients among these parameters are given in Table 1. Among the thermal indices (GDD, HTU and TIR), thermal interception rate was highly related with dry matter and yield. R² values are given in Table 2 which were significant (P < 0.05).

Simple linear models developed based on APAR explained for 90.2 and 60.8 per cent of variation in dry matter and yield, respectively. By taking into account Et, the linear relationship explained 82.8 and 81.0 per cent variability in dry matter and yield, respectively. Spectral indices were highly related with dry biomass and yield during milking stage of the pearl millet crop as given in Table 1. Between the spectral indices the normalised difference (ND) explained the variability in dry matter and yield with maximum accuracy, i.e., 90.2 and 62.0 per cent.

The multiple regression models developed for dry matter and yield, taking into account best two variables, which explained up to 94.2 and 97.2 per cent variation. These R² values were

Table 2 Multiple regression equations relating dry matter and yield of pearl millet with agrometeorological variables and spectral indices

Parameters	Regression equation	R ²
	$Y = a + bx_1 + cx_2$	
DM =	$-18210.0 + 6.60 \text{ APAR} + 38868.20 \text{ ND}$	94.2
YI =	$19337.4 - 30574.7 \text{ ND} + 7.0 \text{ TIR}$	97.2
	$Y = a + bx_1 + cx_2 + dx_3$	
DM =	$-15819.8 + 2.04 \text{ ET} + 6.35 \text{ APAR} + 34578.0 \text{ ND}$	0.944
YI =	$19707.4 - 1.20 \text{ ET} - 31121.2 \text{ ND} + 7.6 \text{ TIR}$	0.973
	$Y = a + bx_1 + cx_2 + dx_3 + ex_4$	
DM =	$-35959.7 + 18.80 \text{ ET} + 8.90 \text{ APAR} + 68568.9 \text{ ND} - 14.2 \text{ TIR}$	0.973
YI =	$18376.9 - 1.90 \text{ ET} - 1.40 \text{ APAR} - 29507.0 \text{ ND} + 8.9 \text{ TIR}$	0.995

DM = Dry matter (kg ha⁻¹)

significant ($P < 0.01$). Based on the best three variables, the regression models were developed for prediction of dry matter and yield. The R² values obtained were highly significant as shown in Table 2. The multiple regression models, developed based on best four of the indices, explained the variability in dry matter and yield with highest percentage, i.e., 0.973 and 0.995 per cent.

Looking into the simple linear models, models using TIR and APAR predict the dry matter and yield of pearl millet with maximum accuracy. Out of the remaining models, models based on two variables are very simple as minimum inputs are required and at the same time much accurate in prediction of dry matter and yield. However, all the above mentioned models work well according to the availability of input parameters. But for highest accuracy in respect of dry biomass and yield prediction, the models based on best four variables are preferred.

It is concluded that dry matter and yield of pearl millet can be predicted with the maximum accuracy using the following models :

$$\text{Dry matter} = -35959.7 + 18.80 \text{ ET} + 8.90 \text{ APAR} + 68568.9 \text{ ND} - 14.2 \text{ TIR} \quad (R^2 = 0.973)$$

$$\text{Yield} = 18376.9 - 1.90 \text{ ET} - 1.40 \text{ APAR} - 29507.0 \text{ ND} + 8.9 \text{ TIR} \quad (R^2 = 0.995)$$

where,

ET = cumulative evapotranspiration

(mm)

APAR = cumulative absorbed photosynthetically active radiation (MJ m⁻² d⁻¹)

TIR = cumulative thermal interception rate (MJ°C day⁻¹) and

ND = normalised difference

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