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Stocheometric crop weather model to predict the fingermillet grain yield

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ABSTRACT

A stocheometric crop weather model to predict fingermillet growth and grain yield based on the dry matter accumulated at each stage has been developed. Multiple linear regression equations relating the GDD, SSH and AET with the accumulated dry matter during each growth stage and also the final grain yield were generated using the field experimental data for the period 1992-98. Total dry matter accumulated at the end of each growth stage could be estimated to an extent of 92 to 98 per cent and explained about 90 per cent variability in yield as indicated by CD value. The model has been validated for the year 1999, revealing good agreement (regression coefficient of 0.99) between the observed and the predicted yields. Favorable influence of AET at the time of beginning of tiller and grain formation stages, and higher GDD during ear emergence and harvest stages was noticed. Increase in AET during pre-harvest stage did not favour good grain yield.

Key words : Crop weather model, Fingermillet, GDD, AET

Fingermillet is an important cereal crop that is annually grown in about 2.6 million hectare with a production of about 3 million tons. Karnataka ranks first with more than 40 per cent of its total dry-land area under fingermillet cultivation, accounting for more than 50 per cent production in the country. Fingermillet is nutritionally comparable to rice and wheat. Productivity of this crop has been gradually increasing inspite of its cultivation under diverse agro-climatic and ecological conditions (Anonymous, 1992). It is because of its low water requirement and capability to withstand higher temperature and little long dry spell. It is well adapted for regions of low to medium rainfall and soils with low nitrogen and organic contents. In the low rainfall region, since the crop is frequently affected by drought, fingermillet is also valued highly for its fodder to meet the requirements of the domestic livestock. These attributes make fingermillet an attractive choice for marginal semi-arid lands.

During sufficient moisture availability periods, fingermillet crop exhibits luxuriant growth with profuse tillering, while stress or competition for moisture due to population density, reduce its effective tillers diverting the biomass partitioning more to the main stem. On the contrary, if the main stem is affected for any reason by biotic or abiotic stress and when favorable weather and soil moisture conditions follow, it can compensate its growth through better development of tillers. In spite of these favorable attributes, under rainfed conditions the crop yield fluctuates widely from year to year depending on the duration of moisture stress at different stages of the crop.

Many attempts were made by scientists viz. Gregory (1926), Victor *et al.* (1991a, b), Nathan (1996) to relate weather parameters with the crop yield. Forecast equations have been developed by Shanker and Gupta (1987) to predict the yield of paddy. Of the several crop weather models, Stocheometric model is one wherein influence of weather on the performance of the crop in each growth stage is considered. As reported information on growth models for fingermillet crop is meager, here an attempt is made to develop a Stocheometric crop growth model for fingermillet. Influence of actual evapotranspiration (AET), growing degree days (GDD) and bright sunshine hours (SSH) prevailing during each stage of the crop on the grain yield have been studied.

MATERIALS AND METHODS

The field experiments were laid out during the years of 1992-98 at GKVK Campus (Altitude 930 m amsl, longitude 77°35' and latitude 12°58') at Bangalore, Karnataka and the crop fingermillet was raised on red sandy loam soils with a depth of more than 2 m following the recommended package of practices. Each year the crop was rotated with a leguminous crop groundnut. Weather data from the adjacent agromet observatory was used. Each year crop was sown on two different dates during 1992 to 1999. During 1992 to 1995, it was sown on three different dates in *kharif* season.

The daily GDD was calculated using 10°C as base temperature and summed up to each crop phenological stage. AET was computed following the FAO water balance method (Doorenbos and Pruitt, 1977). The following phenological stages of fingermillet crop were considered.

1. Sowing to beginning of tiller,
2. Beginning of tiller to ear emergence,
3. Ear emergence to 50 per cent flowering
4. 50 per cent flowering to grain formation
5. Grain formation to harvest.

In the stocheometric crop weather models, it is necessary to consider the initial status of the crop to know the influence of weather parameter on further accumulation of the dry matter. The initial biomass (TDM) of the crop was considered as one of the independent parameters along with the GDD SSH and AET to compute the biomass accumulated at the end of each stage. Multiple linear regression equations were generated using GDD, SSH, AET and the initial TDM as independent parameters and the total dry matter accumulated at the end of each stage as dependent parameter for all the stages.

$$T_1 = (A_1X_1+B_1Y_1+C_1Z_1) \quad \text{---(1)}$$
$$T_2 = T_1s_2 + (A_2X_2+B_2Y_2+C_2Z_2) \quad \text{---(2)}$$
$$T_3 = T_2s_3 + (A_3X_3+B_1Y_3+C_3Z_3) \quad \text{---(3)}$$
$$T_4 = T_3s_4 + (A_4X_4+B_4Y_4+C_4Z_4) \quad \text{---(4)}$$
$$T_5 = T_4s_5 + (A_5X_5+B_5Y_5+C_5Z5) \quad \text{---(5)}$$

Where subscript indicates the respective stages, T_1. . . . . T_5 are the accumulated total dry matter at the end of respective stages. A, B and C are GDD, SSH and AET, respectively, X, Y and Z are the coefficients of the variable GDD, SSH and AET, respectively. s is the coefficient of input accumulated bio-mass.

Grain yield (Y_g) as influenced by the accumulated bio-mass at the end of each stage is related in the equation of the type

$$Y_g = iT_1(o) + jT_2(o) + kT_3(o) + {}_1T_4(o) + mT_4(p)$$

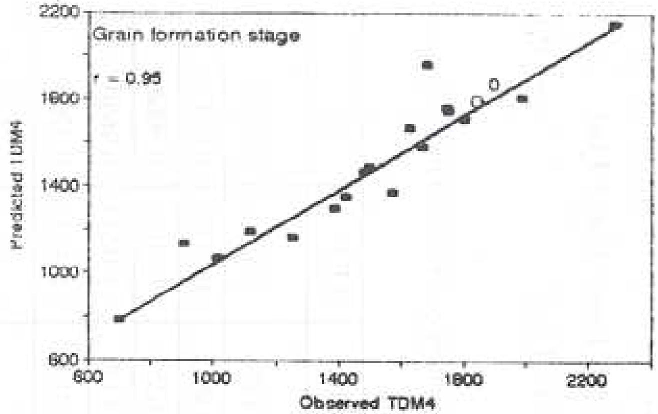

Fig. 1 : Observed and predicted total drymatter (kg ha⁻¹)

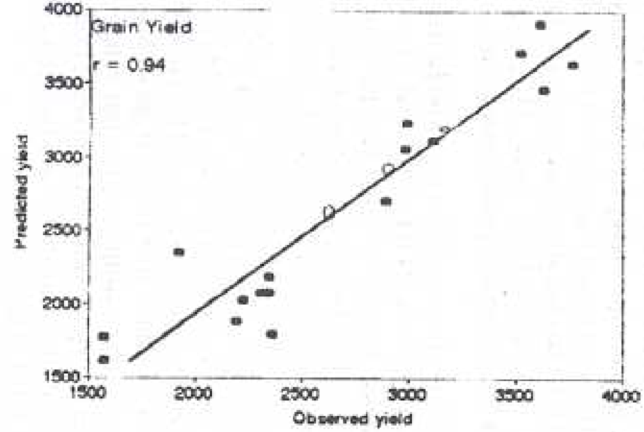

Fig. 2: Observed and predicted grain yield (kgha⁻¹)

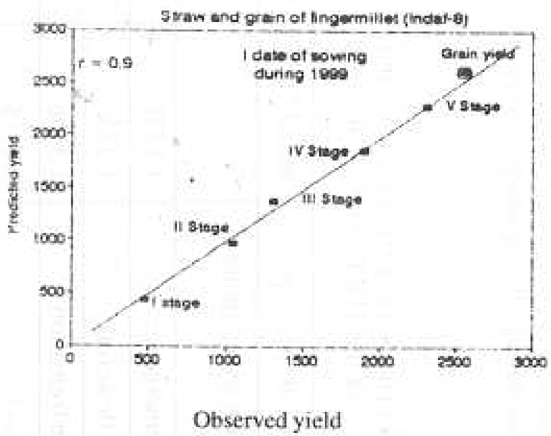

Fig. 3 : Observed and predicted yields (kg ha⁻¹) for first sowing date during 1999.

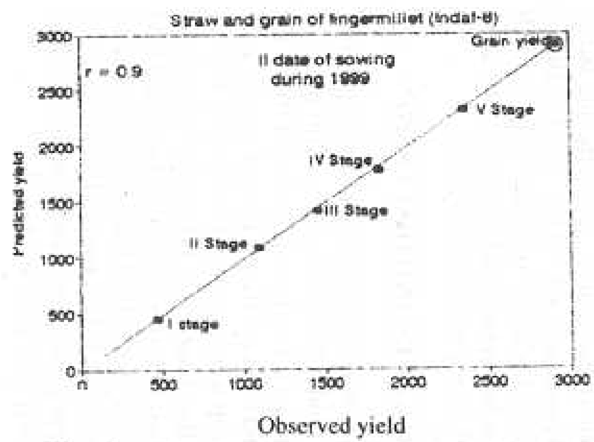

Fig. 4: Observed and predicted yields (kg ha⁻¹) for second sowing date during 1999.

Where $T_1(o)$, $T_2(o)$, $T_3(o)$ and $T_4(o)$ are the observed total dry-matter at the end of first four stages and $T_5(p)$ is the predicted total dry-matter for 5th stage. *i, j, k, l* and *m* are the coefficients. With the help of such equation the grain yield could be estimated well before the harvest of the crop.

RESULTS AND DISCUSSION

Five multiple linear regression equations 1 to 5 (model forced through origin to avoid the constants) for the estimation of the TDM at the end of five different phenological stages of the crop were generated as above (Table 1). Taking the observed TDM accumulated at the end of first four stages and the predicted TDM at the end of fifth (final) stage as independent parameters and the observed grain yield as dependent parameter, another multiple linear equation (Eq.6) was developed.

This analysis indicates that higher GDD is favorable during tillering, ear emergence and 50 per cent flowering stages, while AET is favorable during tillering and grain formation stages. SSH is favorable during harvest stage where GDD is also highly significant. During the 50 per cent flowering and grain formation stages SSH has negative impact on the grain yield. During the tiller stage AET shows significant positive influence on the crop.

When the model was validated for prediction of the TDM at the end of each phenological stage, we found good agreement between the observed and the predicted values. Representative result for predicted TDM at the end of grain formation stage is plotted in Fig. 1. Final grain yield predicted using the observed accumulated TDM at the end of each of the four stages and the predicted TDM at the end of fifth (final) stage is shown in Fig. 2. The multiple regression equation relating the yield with the observed TDM at the end of first four stages and the predicted yield of fifth stage is given by

$$Y_g = -1.845\ T_1(o) + 1.157\ T_2(o) + 1.530\ T_3(o) - 1.4877\ T_4(o) + 1.364\ T_5(p) \quad \text{------(6)}$$

Table 1 : The coefficients of variables and coefficients of determinant generated for the prediction of the TDM and the grain yield.

Stages of the crop	Initial TDM	GDD	SSH	AET	R^2
Sowing to beginning of tillering		1.1054	-1.4476	2.4553	0.9262
Ear emergence	1.1424	2.7711	0.9811	-6.2575	0.9519
50% flowering	1.3356	3.3565	-2.6251	-7.9403	0.9666
Grain formation	1.3468	-0.2362	-1.8339	5.0243	0.9680
Harvest	0.8115	1.2205	4.4548	0.4897	0.9766
Grain yield					0.9195

The model was further validated for the crop raised on two dates during 1999 *kharif*. It was able to predict the TDM (Figs. 3 & 4) in each stage more accurately and the grain yield to an extent of 97.6 per cent for first date of sowing and 98.9 per cent for second date of sowing.

This stocheometric crop weather model consisting of six multiple regressions could be used to predict dry matter at different stages and the grain yield well before the harvest of the crop. Final grain yield also could be estimated with reasonable accuracy in the Bangalore region demonstrating its applicability.

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