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Influence of actual evapotranspiration, growing degree days and bright sunshine hours on yield of finger millet

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सार – इस शोध–पत्र में 1997–1999 तक तीन वर्षों की अवस्थाओं के अंतर्गत खरीफ फसल के दौरान किए गए परीक्षण से प्राप्त हुए परिणामों के आधार पर बंगलुरू में रागी के फसल गुणांक को समय के साथ संबद्ध करते हुए एक निदर्श तैयार किया गया है। बीज बोने के पश्चात 66 वें दिन फसल गुणांक के चरम मान 1.02 पाए गए। वर्ष 1998 से 2005 तक की अवधि के क्षेत्रीय प्रयोगात्मक आँकड़ों का उपयोग करते हुए बीज बोने से लेकर फसल के पकने तक की विभिन्न अवस्थाओं तक वास्तविक वाष्पोत्सर्जन (ए.ई.टी.), फसल की बढ़वार की अवस्थाओं के दिनों (जी.डी.डी.) और तेज धूप के घंटों (बी.एच.एस.) के संचित मानों के आधार पर बहु समाश्रयण समीकरण भी तैयार किए गए। वर्षा की अवस्थाओं के अंतर्गत मंडुआ की पैदावार का पूर्वानुमान लगाने के लिए इस बहु समाश्रयण समीकरण का प्रयोग किया जा सकता है। वर्ष 2005 की खरीफ की फसल के दौरान फसल की बढ़वार के लिए इस निर्दश का समर्थन किया गया है।

ABSTRACT. Based on the result of an experiment conducted for three years from 1997-1999 during Kharif, under rainfed conditions, a model has been generated for relating crop coefficient of ragi with time at Bangalore. The peak value of crop coefficient was found to be 1.02 on 66th day after sowing. The multiple regression equation was also generated based on the accumulated values of actual evapotranspiration (AET), growing degree days (GDD) and bright hours of Sunshine (BHS) from sowing to physiological maturity, using the field experimental data for the period 1998-2005. This multiple regression equation can be applied to forecast the yield of finger millet under rainfed conditions. This model was validated for the crop grown during Kharif 2005.

Key words – Finger millet, Actual evapotranspiration, Growing degree days, Bright hours of sunshine, Crop coefficient, Multiple regression equation.

1. Introduction

Finger millet (*Elusine coracana Gaertn*) is one of the staple food crop of Southern Karnataka and also valued for its fodder to meet the requirements of the domestic livestock. The early prediction of yield is very important for planning and decision making purposes at the national and international levels. Yield prediction would also be useful in the planning of export - import and continuous monitoring of potential areas of crop failure.

Finger millet is mainly grown in rainfed area. It experiences soil moisture stress during prolonged dry spells of southwest monsoon. To overcome the soil moisture stress during dry spells at critical stages, a knowledge of crop coefficient (Kc) is necessary to plan agricultural operations like protective irrigation etc, Doorenbos and Pruitt (1977) showed the significance of Kc for assessment of crop water requirement for irrigation scheduling.

Weather affects crop growth differently at different phonological stages. Ganeshan and Ahobala Rao (1989) found that the duration to flowering is positively correlated with average temperatures and average evaporation in the case of finger millet. The crop growth

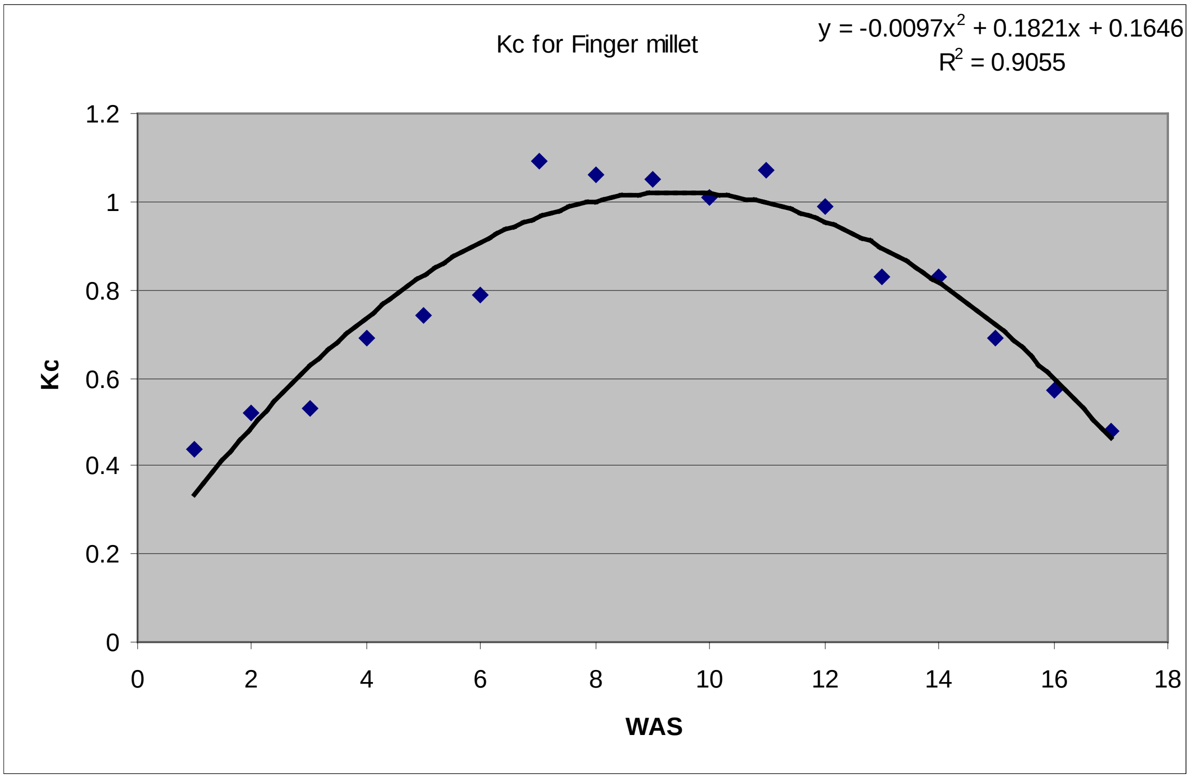

Fig.1. Crop coefficient for Finger millet during 1997-1999

TABLE 1

Accumulated values of AET, GDD & BHS during growth period

Date of sowing	Date of Physiological Maturity	AET (mm)	GDD (degree days)	BHS (hours)	Yield (q/ha)	WUE (kg/ha/mm)	HUE (kg/ha/ degree day)
13 Aug 1997	28 Nov 1997	279.2	–	638.5	–	–	–
13 Aug 1998	30 Nov 1998	297.9	1403.9	574.4	27.82	9.34	1.98
15 Aug 1999	01 Dec 1999	310.7	1400.1	684.8	30.86	9.93	2.20
03 Aug 2000	23 Nov 2000	319.6	1440.9	624.5	31.11	9.73	2.16
29 Jul 2001	25 Nov 2001	345.0	1556.0	610.2	42.74	12.39	2.75
01 Aug 2002	14 Nov 2002	325.0	1446.0	571.4	28.26	8.69	1.95
24 Jul 2003	16 Nov 2003	362.7	1524.0	586.9	37.26	10.27	2.44
24 Jul 2004	14 Nov 2004	357.5	1449.2	661.0	40.97	11.46	2.83
11 Aug 2005	06 Dec 2005	329.3	1453.3	548.9	30.15	9.15	2.07
Average values		325.2	1459.2	611.2	33.65	10.12	2.29

simulation models currently being used extensively for predicting the yield of crops have large input data requirements and some are difficult to use being very detailed (Whisler *et al.*, 1986). Muralidhara and Rajegowda (2002) developed stocheometric crop weather models to predict the finger millet grain yield. Compared to these models, statistical crop weather models are practical tool for the analysis of crop responses to weather.

The objective of the present study is to develop regression equation relating crop coefficient with time. Also an attempt has been made to generate multiple regression model based on the accumulated values of AET, GDD and BHS from sowing to physiological maturity to predict the yield of finger millet.

2. Data and methodology

In the present study, data on finger millet variety GPU 28 grown at Agrometeorological research unit of IMD, GKVK campus, Bangalore (12° 58′ N, 77° 35′ E, 930m asl) in Karnataka state for three years during the Kharif season between (1997-1999) were analysed to study crop coefficient during various growth stages of the crop. The crop was raised on red sandy loam soils following the recommended package of practices of university of agricultural sciences, Bangalore. The crop coefficient (Kc) was calculated using the following relationship

$$Kc = AET/PET$$

Potential evapotranspiration (PET) values were calculated using Penman's modified formulae. The data on meteorological parameter from the adjacent agrometeorological observatory was used. The actual evapotranspiration (AET) was measured through gravimetric lysimetres located in the crop field during the years (1997-1999). AET was calculated for the period (2000-2005) from the calculated values of PET and Kc.

Daily values of maximum and minimum temperatures were used to calculate the heat units namely growing degree day (GDD) keeping 10° C as base temperature from sowing to physiological maturity.

$$GDD = [(T\max + T\min)/2] - T_b$$

where

Tmax = Maximum temperature

Tmin = Minimum temperature

T_b = Base temperature.

Maximum and minimum temperature data for the month of October 1997 is not available. Harvesting data of 1997 for the finger millet is also not available as the GKVK campus, Bangalore recorded 200 mm and 65 mm of rainfall on 1st and 2nd October 1997. Because of this very heavy rainfall the crop might have damaged partly.

Multiple regression equation was generated based on the accumulated values of AET, GDD & BHS (Table 1) from the date of sowing to date of physiological maturity as independent parameters and yield as dependant parameter and was used to estimate the yield of finger millet. This multiple regression was validated for the crop grown during Kharif 2005 at GKVK campus, Bangalore.

3. Results and discussion

3.1. *Crop coefficient*

A knowledge of crop coefficient is necessary to determine water requirement of the crop. Fig.1 shows variation in crop coefficient (Kc) with time, in weeks after sowing (WAS) during the growth of finger millet. When Kc values were fitted to time in WAS, the following non-linear relationship ($R^2 = 0.90$) was obtained

$$Kc = 0.1646 + 0.1821 \times (WAS) - 0.0097 \times (WAS)^2, \quad R^2 = 0.90$$

Using this equation, it is possible to estimate Kc values at any time, during different stages of crop growth. The maximum value of Kc was found to be 1.02 on 66th DAS. Das *et al.*, (1996) found the highest value of Kc *i.e.*, 1.10 for pearl millet at Hissar and occurred at 9th WAS in the flowering stage. Chaudhari *et al.*, (1999) have reported Kc values for major crops of Gujarat region.

3.2. *Consumptive use of water (AET) and water use efficiency (WUE)*

The AET of finger millet varied between 279.2 mm and 362.7 mm (Table 1). This variation may be due to weather conditions prevailing during the growth period in different years. Doorenbos and Kassam (1979) also recognised climate as one of the important factors determining crop water requirements needed for unrestricted optimum growth and yield. The level of evapotranspiration is related to the evaporative demand of

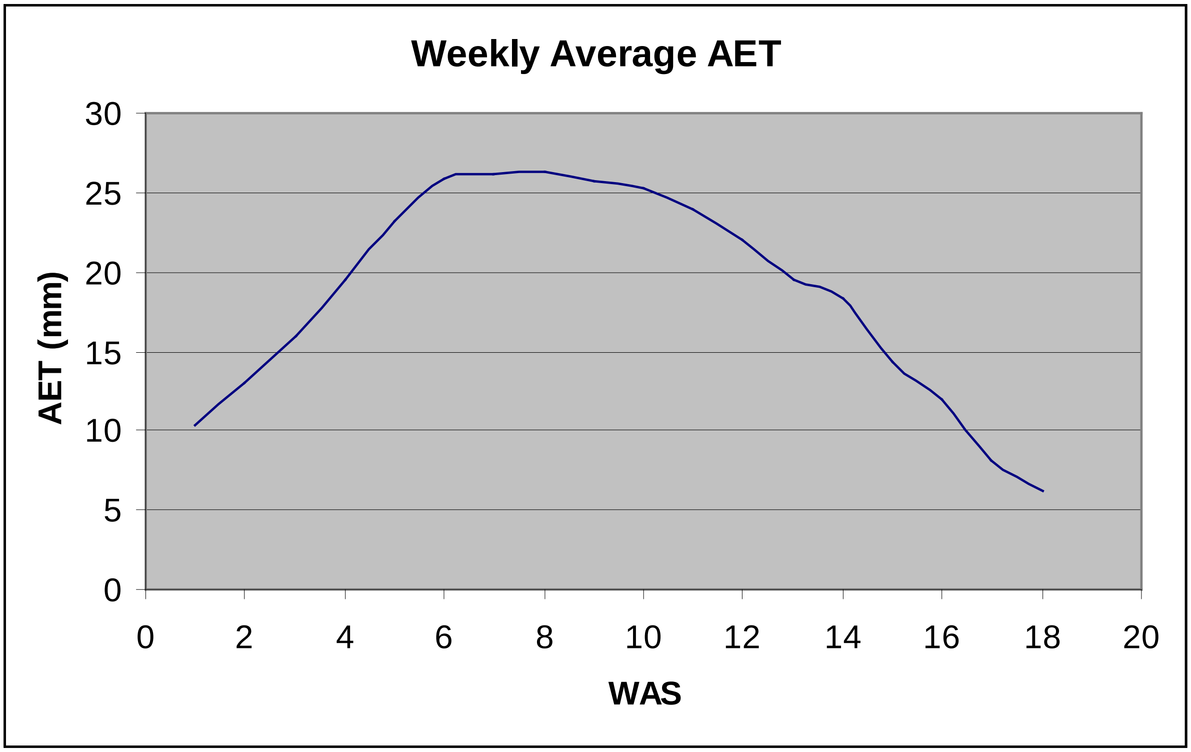

Fig. 2. Weekly Average AET for Finger millet during 1997-2005

the air. On an average the crop need about 325.2 mm of water during the growth period. The variation of average weekly AET with respect to WAS is shown in Fig.2

The yield varied from 27.82 q/ha during 1998 to 42.74 q/ha during 2001 with a mean yield of 33.65 q/ha.

The seed yield and evapotranspiration showed a positive and significant (R^2 = 0.69) linear relationship.

$$Y = 0.208(AET) - 34.92, \qquad R^2 = 0.69$$

The scatter between grain yield and evapotranspiration data (R^2 = 0.69) was probably due to the variation in rainfall amount and distribution among the growing seasons. Zhang and Oweis (1998) reported a linear relationship of grain yield with seasonal evapotranspiration for wheat and also by Stewart *et al.*, (1983) for sorghum. Hati *et al.*, (2001) also reported a significant relationship (R^2 = 0.79) of seed yield and total evapotranspiration for Indian mustard.

The lowest water use efficiency (WUE) of 8.69 kg/ha/mm was observed in 2002 and while highest value of 12.39 kg/ha/mm was in the 2001. The wide variation of WUE may be attributed to the varying crop growing environments in different years.

3.3. *Growing degrees and bright hours of sunshine*

GDD is widely used for describing the temperature response on growth and development of the crops. The crop requires about 1459.2 heat units (GDD) for its maturity. The following equation was obtained between the yield of grain (Y) and accumulated heat units (X), it gives

$$Y = 0.0791\,(GDD) - 81.43, \qquad R^2 = 0.57$$

Mathan (1996) found the values of GDD ranging from 1390 to 1467 for ragi. Ganeshan *et al.*, (1988) reported a linearly correlation between biomass production and accumulated GDD.

TABLE 2

Correlation of AET, GDD & BHS with grain yield

Phonological stages	AET	GDD	BHS
Sowing to tillering	0.10	-0.37	-0.33
Ear emergence	0.32	-0.19	-0.20
50% Flowering	0.60*	-0.02	-0.01
Grain formation	0.67*	0.43	0.24
Maturity	0.52	0.79*	0.53

*Significant at 5% level.

The heat use efficiency (HUE) is ranged from 1.95 kg/ha/degree day to 2.83 kg/ha/degree day as observed in Table 1. Experiment conducted at Coimbatore recorded the values of HUE from 0.68 kg/ha/degree day to 2.84 kg/ha/degree day (Mathan, 1996).

The grain yield and bright hours of sunshine are found to be positively correlated. The average value of bright sunshine was 611.2 hours. Mathan (1996) reported the range of BHS varied from 577.7 hours to 802.7 hours.

3.4. *Multiple regression model and its validation*

The following multiple regression model was generated based on the accumulated values of AET, GDD & BHS from sowing to physiological maturity to predict the yield of finger millet.

$$Y = -125.76 + 0.086\,(AET) + 0.064\,(GDD) + 0.06\,(BHS), \qquad R^2 = 0.93$$

The model has been validated for the crop grown during Kharif 2005 at GKVK campus, Bangalore and the predicted value was found to be 29.40 q/ha where the actual value was 30.15 q/ha. The regression equation containing the parameters AET, GDD & BHS is found to be a good predicting model.

It is found that the AET is significantly correlated with grain yield during flowering and grain formation stage. GDD is significantly correlated with grain yield during maturity stage and the correlation between BHS and grain yield is 0.53 during maturity stage (Table 2).

4. Conclusion

(*i*) Based on the crop coefficient at specific stages, the water requirement for the crop may be worked out so that in command areas highest yield can be realised with the management of available water.

(*ii*) The highest value of crop coefficient was 1.02 on 66^{th} day after sowing.

(*iii*) The average values of AET, GDD and BHS 325.2 mm, 1459.2 degree days and 611.2 hours respectively.

(*iv*) The multiple regression model may be used for yield forecasting of finger millet under rainfed conditions at Bangalore.

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