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A study of the influence of selected weather parameters on biomass production in ragi

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सार — 1982–85 की अवधि के दौरान बंगलूर गांधी कृषि विज्ञान केन्द्र के फार्म में उत्पन्न मंडुवा में जैविक उत्पादन और कुछ चुने हुए प्राचलों, जैसे बढ़ते हुए उष्णांश, खुली कढ़ाई वाला वाष्पीकरण तथा वाष्पोत्सर्जन के बीच सम्बन्ध का पता लगाने का प्रयास किया गया है। इन्डाफ-5 का समीकरण : $Y=e^{a+b\log x}$, जिसमें Y जैविक सस्योत्पति (क्विंटल/हैक्टर) और $x=$ बढ़ता हुआ दैनिक उष्णांक अंक या वाष्पीकरण या वाष्पोत्सर्जन सूचित करता है, अति संतोषजनक है। परिशीलन किए हुए दूसरे समाधान कारक समीकरण है :

$$Y=a+bx,\ Y=a+b\log x \text{ और } Y=e^{a+bx}$$

ABSTRACT An attempt has been made for obtaining a relationship between biomass production in ragi (*Eleusine coracana Gaertn*)—Indaf 5, grown over Bangalore GKVK farm during the period 1982 to 1985 and a few selected weather parameters, namely growing degree days, open pan evaporation and evapotranspiration. The equation of the form $Y = e^{a+b\log x}$, where Y is the biomass production in quintals/hectare and x is the growing degree days or open pan evaporation or evapotranspiration, is most satisfactory. The other forms of equation considered for suitability are :

$$Y=a+bx,\ Y=a+b\log x \text{ and } Y=e^{a+bx}$$

1. Introduction

The biomass production depends upon agricultural practices and along with them on various meteorological parameters. Various relationships have been attempted for expressing biomass production in terms of the parameters, *viz.*, degree days, pan evaporation and evapotranspiration.

Ragi, otherwise known as finger millet (*Eleusine coracana Gaertn*), is one of the hardiest crops. It is grown mainly over Africa and Asia. India alone produces between 40 and 45 % of the total world production and most of the rest of ragi millet is produced in central Africa. Karnataka and Tamil Nadu produce about 61 % of the total crop in India. The southeastern area of Karnataka, adjoining areas of Tamil Nadu and Andhra Pradesh produce the bulk of the Indian crop (Rachie and Peters 1970). According to Ayyangar (1932) ragi grains can be stored for as long a period as 50 years thereby providing a ready store of food for the needy, if droughts prolong for a considerable time. Ragi biomass is the main fodder in most parts of Karnataka, for cattle and other ruminants. Therefore, it is of interest to study the relationship between biomass production and weather parameters, in the case of ragi.

In the present study the weather parameters chosen are Growing Degree Days (G.D.D.), evapotranspiration (E_T) and pan evaporation (E_P).

2. Materials and methods

The same seed variety namely Indaf 5 was used for all the years under consideration. The cultural practices like irrigation, input of fertilisers were done according to the recommended practices. Therefore, the only factor that would affect the growth of the plants can be taken to be weather parameters only.

The observations on biomass of ragi plants were taken first as soon as the plants were well established after the transplantation (which is effected generally about twenty days after the date of sowing) and then subsequently at every fourteen days interval upto the maturity-stage of the crop. Thus, about five biomass observations were taken for each kharif season and about four for each summer season. The total number of observations available for kharif and summer seasons were 20 and 17 respectively during the four-year period under consideration. The biomass was determined by taking random samples from the field. Fresh weights of the biomass were determined immediately and dry weights were determined after drying.

The meteorological records of the observatory located nearby provided the Max. and Min. temperatures, in degree celcius and the open pan evaporation in mm from the U.S.A. class A-type open-pan evaporimeter (E_P). The gravimetric lysimeter installed at the experimental site provided the E_T values for the crops. Taking a base temperature as 10°C for ragi a growing degree day (G.D.D.) was taken to be $[(T_{max} + T_{min})/2] - 10$. The number of degree days was then computed from the date of sowing to each day of biomass observation, for each one of the experiments; similarly accumulated evaporation and accumulated evapotranspiration were computed corresponding to each day of biomass

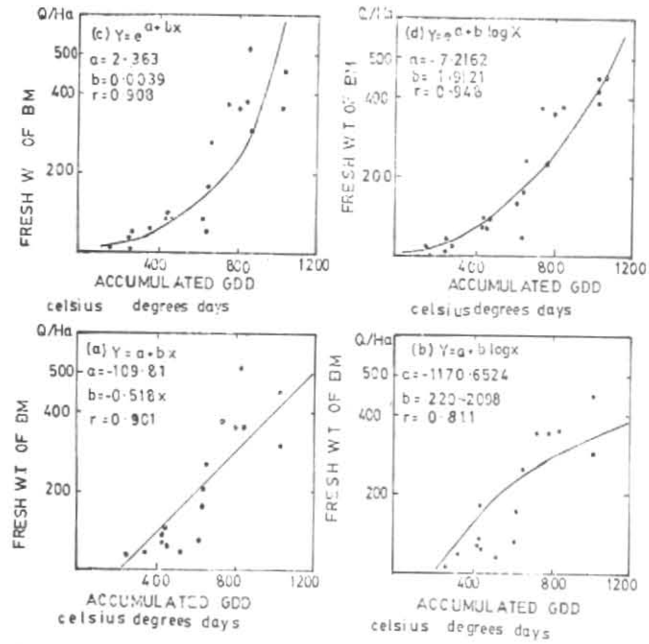

Fig. 1. Regression curves for kharif season based on ragi data, 1982-1985

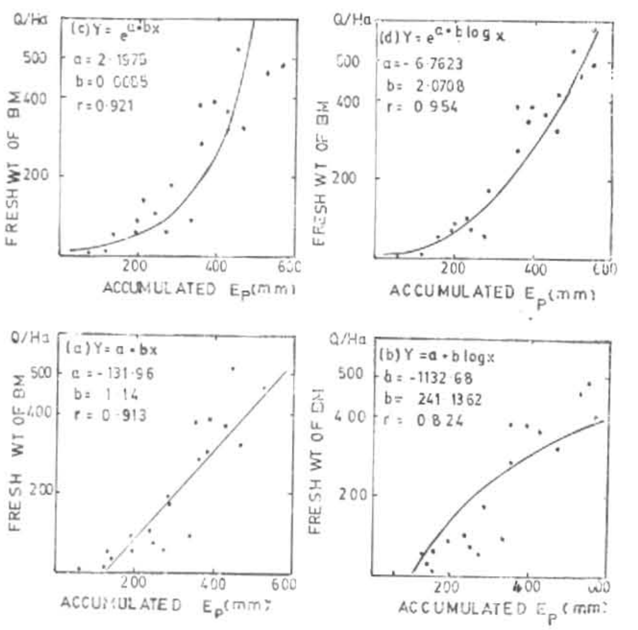

Fig. 2. Regression curves for kharif season based on ragi data, 1982-1985

TABLE 1

Linear regression equation relating biomass (BM) of ragi with weather parameters

Item	Season	*n*	The equation of *Y*	Corr. coeff.
			BM with GDD (Fresh wt)	
GDD	K	20	$Y=-109.81+0.518x$	0.901
GDD	S	17	$Y=-17.2+0.128x$	0.780
GDD	P	37	$Y=-7.5099+0.2256x$	0.567
			BM with GDD (Dry wt)	
GDD	K	20	$Y=-21.00+0.124x$	0.833
GDD	S	17	$Y=-0.77+0.032x$	0.760
GDD	P	37	$Y=4.4412+0.0542x$	0.536
			BM with EP (Fresh wt)	
E_P	K	20	$Y=-131.96+1.14x$	0.913
E_P	S	17	$Y=-17.8105+0.2716x$	0.787
E_P	P	37	$Y=-14.4919+0.4902x$	0.579
			BM with EP (Dry wt)	
E_P	K	20	$Y=-27.39+0.276x$	0.860
E_P	S	17	$Y=0.7348+0.0634x$	0.719
E_P	P	37	$Y=-1.6392+0.1159x$	0.541
			BM with ET (Fresh wt)	
E_T	K	20	$Y=-33.09+1.37x$	0.860
			BM with ET (Dry wt)	
E_T	K	20	$Y=-0.58+0.32x$	0.770

Meaning of symbols same as in Table 2

All values of correlation coefficients significant at $P<0.001$

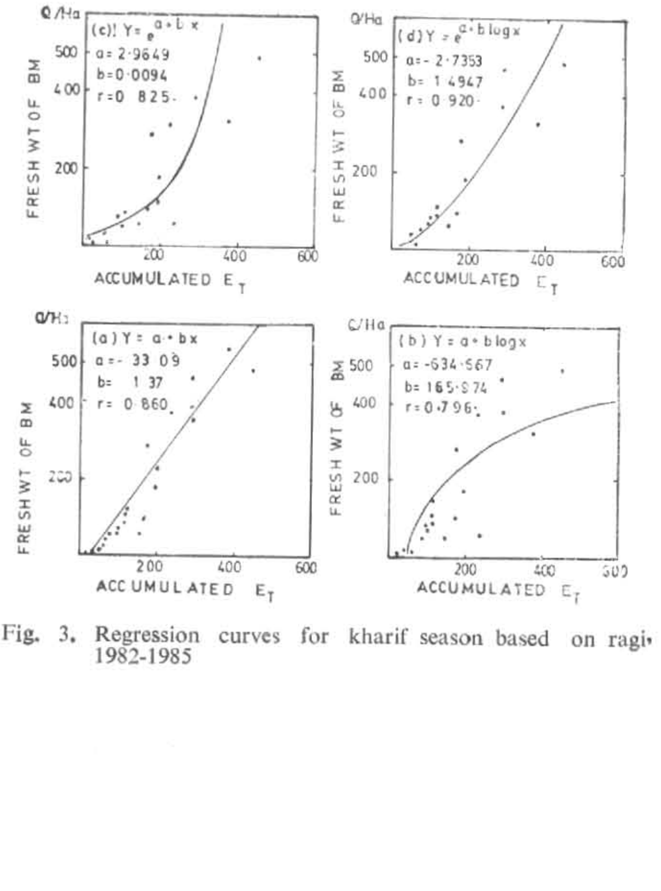

Fig. 3. Regression curves for kharif season based on ragi 1982-1985

TABLE 2

Other regression equations relating biomass (BM) of ragi with weather parameters

Season	n	$Y=a+b \log x$	value of r	$Y=e^{a+bx}$	Value of r	$Y=e^{a+b \log x}$	value of r
				Fresh weight of biomass with GDD			
K	20	$Y=-1170.6524+220.2098 \log x$	0.811	$Y=\exp(2.363+0.0039\,x)$	0.908	$Y=\exp(-7.2162+1.9121 \log x)$	0.948
S	17	$Y=-272.0454+55.3571 \log x$	0.678**	$Y=\exp(1.8864+0.0025\,x)$	0.819	$Y=\exp(-4.7183+1.3381 \log x)$	0.880
P	37	$Y=-555.4727+111.2462 \log x$	0.565	$Y=\exp(2.5136+0.0026\,x)$	0.716	$Y=\exp(-5.0855+1.4884 \log x)$	0.821
				Dry weight of biomass with GDD			
K	20	$Y=-288.3621+54.8831 \log x$	0.780	$Y=\exp(1.199+0.0037\,x)$	0.880	$Y=\exp(-8.2844+1.8775 \log x)$	0.951
S	17	$Y=-70.5146+14.7894 \log x$	0.700**	$Y=\exp(0.9093+0.0023\,x)$	0.787	$Y=\exp(-5.3926+1.2626 \log x)$	0.880
P	37	$Y=-125.2042+26.4325 \log x$	0.544	$Y=\exp(1.4044+0.0024\,x)$	0.702	$Y=\exp(-5.9979+1.4388 \log x)$	0.833
				Fresh weight of biomass with E_P			
K	20	$Y=-1132.68+241.1362 \log x$	0.824	$Y=\exp(2.1975+0.0085\,x)$	0.921	$Y=\exp(-6.7623+2.0708 \log x)$	0.954
S	17	$Y=-215.1475+52.6347 \log x$	0.662**	$Y=\exp(1.9458+0.0051\,x)$	0.800	$Y=\exp(-3.3159+1.2675 \log x)$	0.856
P	37	$Y=-482.4198+112.5695 \log x$	0.562	$Y=\exp(2.4648+0.0056\,x)$	0.719	$Y=\exp(-4.0823+1.501 \log x)$	0.816
				Dry weight of biomass with E_P			
K	20	$Y=-280.0778+60.2921 \log x$	0.797	$Y=\exp(1.0281+0.0081\,x)$	0.893	$Y=\exp(-7.8385+2.0328 \log x)$	0.957
S	17	$Y=-179.3800+12.9335 \log x$	0.661	$Y=\exp(1.0031+0.0046\,x)$	0.751	$Y=\exp(-4.0271+1.1884 \log x)$	0.851
P	37	$Y=-117.5082+28.1445 \log x$	0.555	$Y=\exp(1.3753+0.0052\,x)$	0.698	$Y=\exp(-4.9742+1.4106 \log x)$	0.824
				Fresh weight of biomass with E_T			
K	20	$Y=-634.667+165.974 \log x$	0.796	$Y=\exp(2.9649+0.0094\,x)$	0.825	$Y=\exp(-2.7353+1.4947 \log x)$	0.920
				Dry weight of biomass with E_T			
K	20	$Y=-172.772+46.252 \log x$	0.789	$Y=\exp(1.8172+0.0093\,x)$	0.803	$Y=\exp(-4.1964+1.5548 \log x)$	0.944

Y=Biomass (BM) of ragi in quintals/hec. X=GDD or E_P or E_T, GDD in growing degree centigrade days; log x is calculated with respect to the base 'e'

K=Kharif, S=Summer, P=Pooled data for the two seasons, E_P=Evaporation in mm; E_T=Evapotranspiration in mm

Note : (1) n=number of observations, (2) All values of r significant at $P<0.001$, except the ones marked ** which are significant at $P<0.01$

observation from the date of sowing for each kharif season and each summer season.

Therefore, (1) accumulated G.D.D., (2) accumulated E_T, (3) accumulated E_P and (4) biomass fresh and dry weights for four years are available to study the relationship of biomass with each one of the first three mentioned above.

3. Discussion

Chakravarty and Sastry (1983) presented a linear regression relation between biomass production and G.D.D. and evaporation in the case of mung and wheat. Their studies were based on data of two seasons. It was, therefore, considered desirable as in the case of maize study by the authors, to obtain a simple linear regression relationship and examine the same in respect of (1) biomass production and accumulated G.D.D., (2) biomass production and accumulated E_P and (3) biomass production and accumulated E_T for each kharif and summer season separately and then for all the seasons pooled together. In the case of E_T only kharif season has been considered. The results are presented in Table 1. The correlation coefficients obtained between biomass production and G.D.D. are all highly significant even at $P<0.001$ in the case of kharif and summer seasons being considered separately and values, range from 0.719 to 0.913; but in the case of pooled data the correlation coefficients range from 0.536 to 0.579. It is significant at $P<.001$ also. Figs. 1(a), 2 (a), 3 (a) give some examples of linear regression curves and they are self-explanatory.

It was then decided to examine whether the following curves can give a better fit in the least square sense :

$$Y = a + b \log x \tag{1}$$

$$Y = e^{a+bx} \tag{2}$$

$$Y = e^{a+b \log x} \tag{3}$$

where Y represents the biomass production (wet or dry) and 'x' represents (a) accumulated G.D.D. or (b) accumulated E_P or (c) accumulated E_T. Table 2 which is self-explanatory gives these equations.

The 'r' values, *i.e.*, coefficients of correlations between the variables for the form of the equations concerned when the same are recast in the linear form indicate the satisfactory fit between the BM and accumulated G.D.D., BM and accumulated E_P and BM and accumulated E_T separately seasonwise as well as when all the seasonal data were pooled together. It is of interest to bring out certain salient features of the Tables 1 and 2.

(*i*) Among the forms of equations considered here as indicated in Table 2, the most satisfactory is Eqn. (3), next is Eqn. (2) then $Y = a + bx$ and the least satisfactory is Eqn. (1).

(*ii*) The value of correlation coefficients between G.D.D. and fresh biomass are of the order 0.85 but for pooled data it is 0.57. Thus, the correlation co-efficients are significant at $P < 0.001$. However, the '*r*' value as applying the Eqn. (3) is of the order of 0.91 for individual seasons and the '*r*' value for pooled data is 0.82 and these are significant at $P<0.001$.

(*iii*) The value of correlation coefficients between G.D.D. and dry biomass are in general lower than those between G.D.D. and fresh biomass. The *r* value applicable for the Eqn. (3) for this case are not different from those of the former case. In both the cases the higher value is obtained for kharif season.

(*iv*) In general, the correlation coefficient between E_P and dry biomass is lower than that between E_T and fresh biomass. Here too, the correlation coefficient between E_P and biomass for individual seasons is significant at $P<0.001$. But the correlation coefficient between pooled data E_P and biomass is less than that for individual seasons though significant at $P<.001$.

(*v*) The *r* values obtained on application of the equation of the form (Eqn. 3) vary from 0.851 to 0.957 for individual seasons (E_P *vs* wet wt. and E_P *vs* dry wt. were considered). In the case of pooled data it is 0.82. They are significant at $P < .001$.

(*vi*) The value of correlation coefficient between E_P and dry biomass is lower than that between E_T and fresh biomass.

(*vii*) The *r* values applicable for the Eqn. (3) are also not different in the cases of E_T and fresh biomass, and E_T and dry biomass.

As can be seen from the Tables 1 and 2 and Figs. 1(a) to (d), 2(a) to (d) and Fig. 3 (a) to (d) the most satisfactory equation describing the relationship between biomass and the G.D.D. E_P and E_T respectively is of the form of Eqn. (3). If we choose Eqn. (3) it implies $\triangle Y = b.\ Y \triangle x/x$. That is to say, the increase in biomass is proportional not only to $\triangle x$ but also to Y and inversely proportional to x. Only under the same conditions of ragi plants having same biomass and the same accumulated G.D.D. or E_T or E_P the increase in biomass will be proportional to increase in G.D.D. or E_T or E_P and not otherwise.

The increase in biomass is also governed by the status of already acquired biomass namely Y and already acquired input namely 'x'. For example, suppose G.D.D. is taken as 'x', then if suppose the ragi plants are having same G.D.D. but different biomasses, and when they are subject to equal inputs of heat units, the response of the plants of the larger biomass will be greater; on the other hand the plants which have the same biomass but are subject to different temperature regimes will have different responses in terms of biomass to the same increase in G.D.D. Similar reasonings can be extended to E_P and E_T as x values.

4. Conclusions

(*i*) The equation of the form $Y = e^{a+b \log x}$, where Y is the biomass and 'x' is the accumulated G.D.D. or E_T or E_P is the most satisfactory equation relating BM and weather parameters, among the forms of equation discussed here.

(*ii*) The equation of the form $Y = a + b \log x$ is least satisfactory.

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