Journal of Agrometeorology 8(2) : 186 - 191 (Dec. 2006)

Thermal indices for major crops and prediction of growth and yield of finger millet in hilly southeastern Orissa state

S.SUDHISHRI* and A.DASS

Central Soil and Water Conservation Research and Training Institute, Research Center, PB No. 12, Sunabeda- 763 002, Koraput (Orissa)

ABSTRACT

Accumulated thermal time and heat use efficiency of major crops of southeastern region of Orissa state were computed. Among cereals jhola (low) land paddy, among vegetables brinjal and among pulse crops pigeon pea needed highest thermal time. As finger millet is the staple food of tribals in this region, a field trial in farmers field were conducted in two watersheds developed by Central Soil and Water Conservation Research and Training Institute, Research Center, Sunabeda from 1999 to 2004 using three improved varieties. The results revealed that on an average ragi crop needed 1840 growing degree-days with HUE of 1.05 kg ha^{-1} $^{0}C^{-1}$ day for attaining physiological maturity Results suggested an exponential and linear relationship between HUE and grain yield and AGDD and grain yield, respectively.

Key words: Thermal time, finger millet, southeastern Orissa.

The growth and productivity of crops depend on the elements of the physical environment in a particular ecosystem. Temperature based indices such as growing degree days (GDD), heat use efficiency (HUE), heliothermal (HTU) and photothermal units (PTU) can be relatively useful in predicting growth and yield of crops. Efficiency of conversion of heat energy into dry matter depends upon genetic factors, sowing time and crop type (Rao *et.al.* 1999). Using thermal based indices attempts also have been made earlier to predict phenology (Hundal *et.al.* 1997), leaf area index (Benbi, 1994), growth rate (Kar and Chakravarty, 1999) and growth and yield (Hundal *et.al.* 2003a, b) of crops.

Such studies are lacking for southeastern region of Orissa. Koraput district, a representative of southeastern region was taken for this study and the different areas in this district are situated at altitude ranging between 150 to1000 meters above the MSL and characterized by scattered, sharp, isolated hills with thin forest (Anonymous, 2001). Climate is warm and humid with annual mean maximum and minimum temperature of 30.6°C and 17.0 °C, respectively, and the normal rainfall of

Present Address : Water Technology Center, IARI, Pusa, New Delhi- 110 012

the district is 1521.8 mm. The cultivated area of the district is 3.02 lakh ha; out of which 74 % is rainfed. High, medium and low land constitute 54.9, 25.5 and 19.2 % of the cultivated area, respectively. Agriculture is the main stay of the tribal people of the district, with rice and ragi (finger millet) forming staple food. The other important crops of the district are small millets, maize, vegetables, horse gram and niger. Although cultivated in smaller area, crops like cotton, sugarcane, ginger and turmeric are regarded as important cash crops in the district.

In view of the above, the present study was undertaken to develop a regression model for prediction of growth and yield of ragi (*Eleusine coracana*) in southeastern region of Orissa state.

MATERIALS AND METHODS

The climatological data on temperature and sunshine hours collected from Mixed Farm, Semiliguda and Meteorological observatory of CSWCRTI, Research Center, Sunabeda have been used for the present analysis. The information related to crop duration and length of different stages of the commonly grown field and vegetable crops were collected from the local source. Average yield data for various crops were collected from Statistical Department, Koraput.

Thermal indices

Growing degree-days (GDD) were accumulated from the date of sowing to harvesting of crop to give accumulated GDD (^{0}C days) using base temperature of 5^{0}C.

Heat use efficiency (HUE) was computed using the formula:

$$HUE = \frac{\text{Grain or Biomass yield (kg ha}^{-1})}{\text{Growing degree days (°C days)}}$$

Heliothermal units (HTU) are the product of GDD and corresponding actual sunshine hours for that day.

Photothermal units (PTU) are the product of GDD and corresponding day length for that day.

All thermal units were accumulated from the date of sowing to each date of sampling.

Prediction of growth and yield of ragi

For prediction of growth and yield, data of three varieties (Bhairabi, VL-149 and Subhra) of finger millet grown in a varietal trial conducted at Central Soil and Water Conservation Research and Training Institute, Research Center, Koraput were used. Crops were raised in two watersheds (i) Kokriguda (from 1999 to 2001), and (ii) Malipungar (from 2002 to 2004) in Semiliguda block during *kharif* season following the recommended package of practices of RRTTS, Orissa University of Agriculture and Technology, Semiliguda.

RESULTS AND DISCUSSIONS

Thermal time indices for major crops

Table 1: Thermal indices for major crops in southeastern region of Orissa state

Crop	Length of growing season (No. of days)	Yield (kg ha^{-1})	GDD (^{0}C days)					HUE (kg ha^{-1} ^{0}C^{-1} day)	HTU	PTU
			Initial stage	Crop development stage	Mid season stage	Late season stage	Total			
Kharif										
Upland paddy	15/06 to 23/09 (100)	1030	387	458	620	364	1847.5	0.56	4510	23683
Jhola paddy	01/07 to 07/11 (130)	1540	371	711	901	314	2296.8	0.67	8416	28336
Ragi	01/07 to 18/10 (110)	691	371	621	636	355	1983.3	0.35	6346	24760
Ground nut	15/06 to 03/10 (110)	820	481	631	537	383	2032.3	0.40	5588	25871
Pigeon pea	15/06 to 28/10 (135)	413	481	720	831	426	2457.8	0.17	8091	30734
Black gram	01/07 to 08/10 (100)	428	283	625	629	274	1810.5	0.24	5402	22798
Maize	15/06 to 23/10 (130)	1197	481	720	831	345	2377	0.50	7621	29806
Tomato	01/08 to 28/11 (120)	9481	440	637	665	266	2008.8	4.72	9421	24006
Brinjal	15/06 to 12/11 (150)	9481	576	710	907	491	2683.9	3.53	9506	33287
French bean	01/07 to 28/09 (90)	5430	371	412	537	272	1628.7	3.33	4376	20695
Ginger	15/05 to 01/01 (232)	1434	884	1271	1406	434	3994.4	0.36	19396	49086
Turmeric	15/05 to 11/01 (242)	2147	884	1362	1432	424	4101.3	0.52	20256	50241
Rabi										
Paddy	01/01 to 30/04 (120)	1446	228	533	876	462	2098.7	0.69	18682	24419
Niger	01/09 to 14/12 (105)	371	363	534	515	235	1647.5	0.23	10137	19056
Wheat	15/11 to 15/03 (122)	1193	247	349	662	451	1692.2	0.70	14785	18774
Cole crops	15/09 to 23/01 (130)	9481	543	539	474	306	1860.9	5.09	13220	20970
Chilli	01/12 to 29/05 (180)	810	352	449	1728	617	3146	0.26	27722	37132
Tomato	15/09 to 13/01 (120)	9481	543	539	412	237	1730.7	5.48	12051	19552
French bean	15/09 to 14/12 (90)	5430	455	411	339	187	1391.4	3.90	9309	15888

Table 2: Thermal indices and yield of *ragi* during different years at two watersheds

Watershed	Crop year	Variety	Sowing date	Accumulated GDD °C days)	Grain yield (kg ha^{-1})	HUE (kg ha^{-1} °C^{-1} day)
Kokriguda	1999	Bhairabi	16-Jul	1977	1510	0.76
		VL-149	20-Jul	1771	1307	0.74
	2000	Bhairabi	14-Jul	1902	1750	**0.92**
		VL-149	14-Jul	1763	1530	0.87
	2001	Bhairabi	12-Jul	1930	2250	**1.17**
		VL-149	12-Jul	1804	1840	1.02
Malipungar	2002	Bhairabi	25-Jul	1687	950	0.56
		VL-149	25-Jul	1607	1025	0.64
		Subhra	25-Jul	1740	908	0.52
	2003	Bhairabi	12-Jul	2010	3133	1.56
		VL-149	12-Jul	1877	2383	1.27
	2004	Bhairabi	10-Jul	1990	3550	1.78
		VL-149	10-Jul	1858	2933	1.79
Mean				1840	1928.38	1.05
SD				123.6	864.8	0.4
CV (%)				6.7	44.8	42.1

Accumulated heat units i.e. GDD, HUE, HTU and PTU are given for the major crops of this region in Table 1. It is evident that among cereals highest number of units are needed by jhola (low) land paddy owing to the cultivation of long duration varieties in *kharif* season. Among vegetables brinjal requires highest accumulated units. Between two pulse crops considered here, pigeon pea because of its longer duration recorded highest GDD, PTU and HTU but lower HUE than black gram. Between two spices, ginger and turmeric, all the indices recorded higher values in respect of turmeric. Further, *rabi* crops in general completed their cycle with relatively lesser values of thermal indices as compared to *kharif* crops. However, among *rabi* season field crops, paddy had highest values of GDD, HTU and PTU whereas HUE was the highest with wheat. In case of vegetables, highest GDD, HTU and PTU were observed for chilli and HUE for tomato.

Indices for ragi crop

Accumulated growing degree days (AGDD) were computed for different improved varieties of Ragi i.e. Bhairabi, VL-149 and Subhra from sowing to physiological maturity. HUE was also computed to determine the grain yield produced per unit of growing degree days (Table 2). It was observed that Bhairabi variety availed more

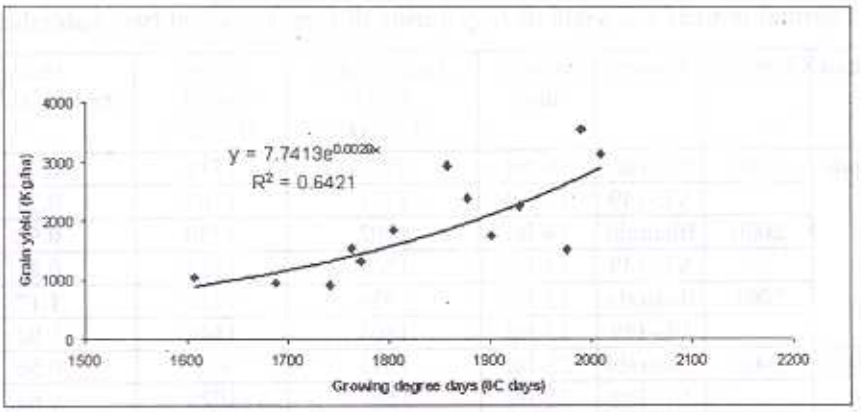

Fig. 1 : Relationship between accumulated growing degree days and grain yield in improved ragi varieties

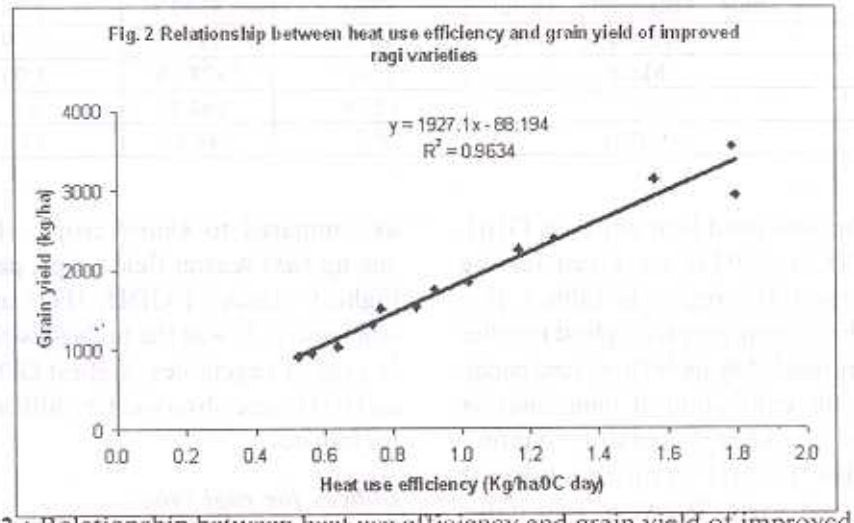

Fig. 2 : Relationship between heat use efficiency and grain yield of improved ragi varieties

AGDD and HUE to attain physiological maturity than VL-149. The results revealed that on an average ragi crop needed 1840 growing degree-days with HUE of 1.05 kg ha^{-1} $^0C^{-1}$ day.

Relationship between thermal indices and grain yield

Relationships between accumulated GDD vs. grain yield, and HUE vs. grain yield were developed separately. It was

observed that there exists a significant exponential relationship between AGDD and grain yield (Fig. 1) and significant linear relationship between HUE and grain yield (Fig. 2) as follows:

$Y = 7.7413\ e^{0.0029X}$ $(R^2 = 0.64)$

Where Y = grain yield (kg ha^{-1}), X = accumulated growing degree-days (°C day)

$Y = 1927.1X - 88.194$ $(R^2 = 0.96)$

Where, Y = grain yield (kg ha^{-1}), X = heat use efficiency (kg ha^{-1} $^{0}C^{-1}$ day)

Similar finding have been reported for wheat by Kaur *et.al.* (2004) for Punjab condition. These relationships can be used for forecasting of ragi yield in southeastern region of Orissa.

ACKNOWLEDGEMENT

The authors are grateful to Sh. S.Kindal, T-2 for helping in collection of meteorological data from different Departments and analysis.

REFERENCES

Anonymous. 2001. Strategic Research and Extension Plan of Koraput district. MANAGE. National Institute of Agricultural Extension Management, Rajendranagar, Hyderabad, India.

Benbi, D.K. 1994. Prediction of leaf area indices and yields of wheat. *J. Agric. Sci.* (Cambridge), 122: 13-20.

Hundal, S.S., Singh, R. and Dhaliwal, L.K. 1997. Agro-climatic indices for predicting phenology of wheat (*Triticum aestivum*) in Punjab. *Indian J. Agric. Sci.*, 67 (6): 265-268.

Hundal, S.S., Prabhjyot-Kaur and Malikpuri, S.D.S. 2003a. Agroclimatic models for prediction of growth and yield of Indian mustard (*Brassica junea) Indian J Agric. Sci.*, 73(3): 142-44.

Hundal, S.S., Singh, H., Prabhjyot-Kaur and Dhaliwal, L.K.. 2003b. Agroclimatic models for prediction of growth and yield of soybean (*Glysine max*). *Indian J. Agric. Sci.*, 73(12): 668-70.

Kaur, P, Dhaliwal, L.K. and Hundal, S.S. 2004. Agrometeorological indices for predicting growth and yield of wheat (*Triticum aestivum*) under Punjab conditions. *J. Agrometeorol.*, Vol. 6 (Sp. issue 2004): 16-20.

Kar, G. and Chakravarty, N.V.K. 1999. Thermal growth rate, heat and radiation utilization efficiency of Brassica under semi-arid environment. *J. Agrometeorol.*, 1(1):41-49.

Rao, V.U.M., Singh, D. and Singh, R. 1999. Heat use efficiency of winter crops' in Haryana. *J Agrometeorol,*. 1(2): 143- 148.