Journal of Agrometeorology 7 (2) : 255 - 261 (Dec 2005)

Growth and yield response of rice (*Oryza sativa*) in relation to temperature, photoperiod and sunshine duration in Punjab

S.S. HUNDAL, PRABHJYOT-KAUR and L.K. DHALIWAL
Department of Agricultural Meteorology
Punjab Agricultural University,
Ludhiana – 141 004

ABSTRACT

Three regression models based on Growing degree days (GDD), Heliothermal units (HTU) and Photothermal units (PTU) were obtained for prediction of growth and yield of rice. Field experiments were conducted using three cultivars of rice during *"kharif"* seasons of 1997, 1998 and 1999 at Ludhiana. The age of seedlings at transplanting was 30, 45 and 60 days. Leaf area development, dry matter accumulation and grain yield were correlated with GDD, HTU and PTU. Higher values of agroclimatic indices were observed for early sown rice cultivars to attain maturity. The highest HUE of 0.896 g m^{-2} per °C day for dry matter and 3.63 Kg ha^{-1} $°C^{-1}$ day for grain yield was recorded for 45 days old seedling transplantation treatment with cv. PR-111. Significant linear and exponential relationships were observed for leaf area index and above ground biomass of rice with the three agroclimatic indices. The model equations can be applied to predict rice growth using daily information on temperature, photoperiod and sunshine during the crop season.

Key words : *Oryza sativa*, Temperature, Photoperiod, Sunshine duration, GDD, PTU, HTU, Heat use efficiency

Rice is one of the most important cereal crops in India. Temperature and light combination plays a key role in influencing rice production since the light intensity requirement for rice is higher and temperature dependent. The crop growth simulation models currently being used extensively for predicting growth and yield of crops have large input data requirements and some are difficult to use, being very detailed (Whisler *et al*, 1986). Therefore, growth and yield prediction models which have less input data requirement would be quite useful. To achieve this goal, agroclimatic models based on thermal indices can play an important role. Attempts have been made by different workers to predict phenology (Hundal *et al*, 1997), leaf area index (Benbi, 1994), growth rate (Kar and Chakravarty, 1999; Singh *et al*, 1996) and growth and yield (Hundal *et al*, 2003) of crops using thermal indices.

Heat use efficiency (HUE), i.e., efficiency of utilization of heat in terms of dry matter accumulation has a great practical application (Rao *et al*., 1999).

Keeping this in view, HUE of different rice cultivars were computed under varying environments alongwith prediction of growth and yield of rice with three agroclimatic models based on Growing degree days (GDD), Heliothermal units (HTU) and Photothermal units (PTU).

MATERIALS AND METHODS

Field experiments were conducted during three consecutive *"kharif"* seasons of 1997 to 1999 using commonly sown cultivars of rice. Rice cv. PR-111; PR-113 and PR-114 were studied at the Research Farm of Punjab Agricultural University, Ludhiana (30° - 54' N latitude; 75° - 48' E longitude, and 247m amsl). The normal maximum temperature, minimum temperature and rainfall during *"kharif"* season at Ludhiana are 34.9 °C , 22.8 °C and 638 mm, respectively (Hundal and Prabhjyot-Kaur, 2002).

The nursery sowing of rice was done in the first and second fortnight of May. The age of the seedlings was kept variable for the cultivars (cv. PR-111 was transplanted at 30, 45 and 60 days after nursery sowing during *kharif* 1997 through 1999; cv. PR-113 was transplanted at 30 days after nursery sowing during *kharif* 1998; and cv. PR-114 was transplanted at 30 and 45 days after nursery sowing during *kharif* 1999 as shown in table 1). The crop was raised following the recommended package of practices of the Punjab Agricultural University, Ludhiana. In order to relate crop growth parameters with agroclimatic indices, plant samples were collected periodically at 15 days interval and leaf area index and dry matter accumulation were recorded.

Growing Degree Days (GDD) were determined using base temperature of 10 °C and were accumulated from the date of nursery sowing to each date of sampling to give accumulated GDD. Heliothermal units (HTU) and Photothermal units (PTU) were computed on daily basis as follows :

HTU = (GDD) x (Actual sunshine hours)
PTU = (GDD) x (Daylength)

Heliothermal units (HTU) and Photothermal units (PTU) were accumulated from the date of nursery sowing to each date of sampling to give accumulated value.

Leaf area index, dry matter accumulation and grain yield were related with accumulated GDD, HTU and PTU in linear as well as exponential relationships as in some cases linear relationship was not the best fit relationship. Heat use efficiency (HUE) for biomass and economic yield (grain yield, kg/ha) were computed to compare the relative performance of different rice cultivars and treatments with respect to utilization of heat using the formula

$$HUE = \frac{\text{Total dry matter } (g\ m^{-2})}{\text{Accumulated heat units } (^{\circ}C\ day)}$$

RESULTS AND DISCUSSION

Agroclimatic indices and crop maturity :

Agroclimatic indices, i.e., GDD, HTU and PTU were computed for rice cultivars

Table 1 : Agroclimatic indices (from sowing to physiological maturity) of rice cultivars for different treatments

Year	Cultivar	Date of nursery sowing	Date of transplanting	Accumulated GDD (°C day)	Accumulated HTU (°C day hour)	Accumulated PTU (°C day hour)
1997	PR-111	06-05-97	05-06-97	2133	17547	29767
		21-05-97	20-06-97	2112	16136	29318
		06-06-97	05-07-97	2066	15668	28280
		06-05-97	20-06-97	1910	16685	27120
		21-05-97	05-07-97	1845	14921	25885
		06-05-97	05-07-97	1885	16102	26285
1998	PR-111	22-05-98	22-06-98	1904	16214	26344
		06-06-98	07-07-98	1837	15675	25827
		22-05-98	07-07-98	2112	16136	29318
	PR-113	22-05-98	22-06-98	1845	19043	31052
1999	PR-111	12-05-99	11-06-99	2219	19070	30691
		27-05-99	26-06-99	2370	19224	32844
		12-05-99	26-06-99	1621	14880	23251
	PR-114	12-05-99	11-06-99	1885	16102	26285
		27-05-99	26-06-99	1904	16214	26344
		12-05-99	26-06-99	2219	19070	30691

under different treatments from nursery sowing to physiological maturity. In early sown rice cultivars higher values of agroclimatic indices (Table 1) were observed for the crop to attain maturity. However, when age of seedling increased, then comparatively lower values of agroclimatic indices were obtained for rice to attain physiological maturity. Rice cv. PR-111 required higher value of these indices to attain physiological maturity compared to cv. PR-113 and PR-114. However, when cv. PR-114 was transplanted after 45 days, it utilized more units than cv. PR-111.

Total dry matter accumulation/Grain yield and heat use efficiency (HUE)

In general, more dry matter was accumulated in early sown as compared to late sown crop (Table 2). However when age of seedling at the time of transplanting increased, lesser dry matter was accumulated in most of the treatments resulting in reduction in grain yields. The highest HUE of 0.896 g m^{-2} per °C day for dry matter and

3.63 kg ha^{-1} per $°C^{-1}$ day for grain yield was recorded for 45 days old seedling transplantation treatment in case of the cv.

Table 2 : Heat use efficiency (HUE) of rice cultivars for different treatments using "GDD

Year	Cultivar	Age of Seedling (Days)	Total dry matter ($g\ m^{-2}$)	Grain yield ($Kg\ ha^{-1}$)	HUE of biomass with GDD ($g\ m^{-2}$ per °C day)	HUE of grain yield with GDD ($Kg\ ha^{-1}$ per °C day)
1997	PR-111	30	1669	5629	0.782	2.64
		30	1434	4836	0.679	2.29
		30	1330	5204	0.644	2.52
		45	1282	4632	0.671	2.43
		45	1221	4362	0.662	2.36
		60	1099	4897	0.583	2.60
1998	PR-111	30	1389	4628	0.730	2.43
		30	1357	4311	0.739	2.35
		45	1435	4158	0.679	1.97
	PR-113	30	1536	4595	0.833	2.49
1999	PR-111	30	1442	5790	0.650	2.61
		30	1321	5310	0.557	2.24
		45	1452	5890	0.896	3.63
	PR-114	30	1202	4680	0.638	2.48
		30	1416	4380	0.744	2.30
		45	1572	5670	0.708	2.56

PR-111, though in most of the cases HUE decreased when the age of seedling increased.

Relationship between leaf area index (LAI) and agroclimatic indices:

The regressions obtained between GDD, HTU and PTU as independent variable and leaf area development upto maximum LAI as dependent variable are shown in Fig. 1 through 3, respectively. Significant relationship between LAI and GDD (R^2 = 0.66); LAI and HTU (R^2 = 0.56); and LAI and PTU (R^2 = 0.63) were observed in exponential relationship for different treatments, but the linear relationships were not found significant because leaf area development occurs exponentially in rice crop.

Total dry matter (TDM) and agroclimatic indices:

The regressions obtained between GDD, HTU and PTU as independent variable and total dry matter (TDM) accumulation in above ground biomass of rice as dependent variable are shown in Fig. 4 through 6, respectively. Significant relationship between TDM and GDD (R^2 = 0.80); TDM and HTU (R^2 = 0.75); and LAI and PTU (R^2 = 0.81) were observed in linear relationship for different treatments in rice crop.

Attempt was also made to correlate grain yield to GDD, HTU and PTU, but no significant relationship could be worked

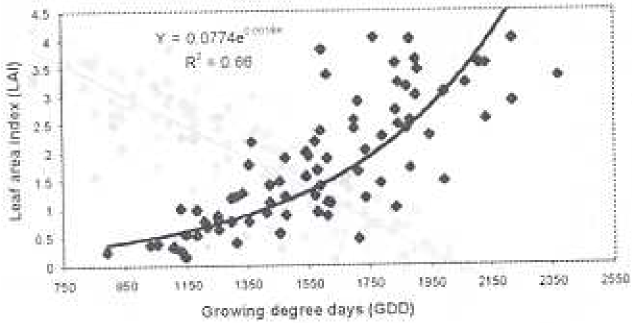

Fig. 1 : Relationship between leaf area index and growing degree days in rice

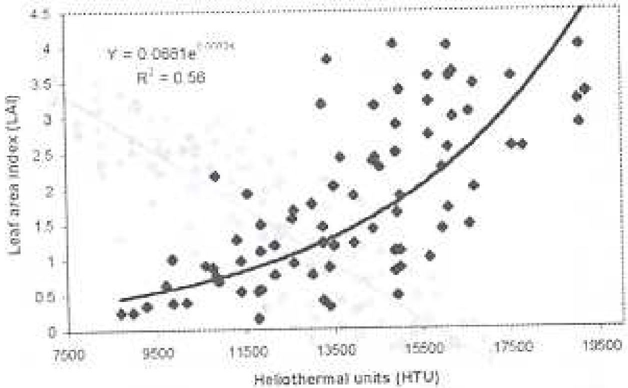

Fig. 2 : Relationship between leaf area index and helothermal units in rice

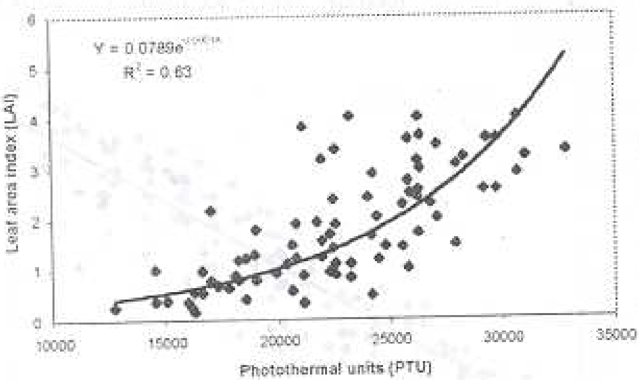

Fig. 3 : Relationship between leaf area index and photothermal units in rice

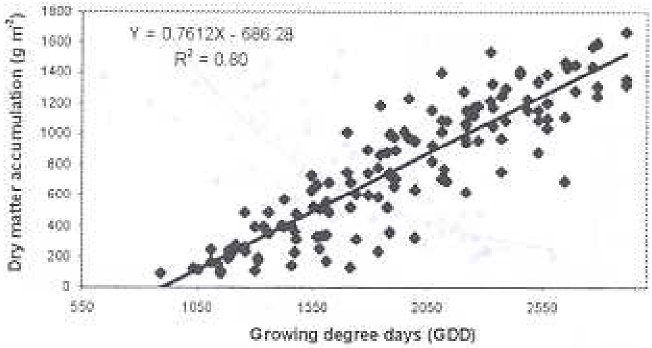

Fig. 4 : Relationship between total dry matter accumulation and growing degree days in rice

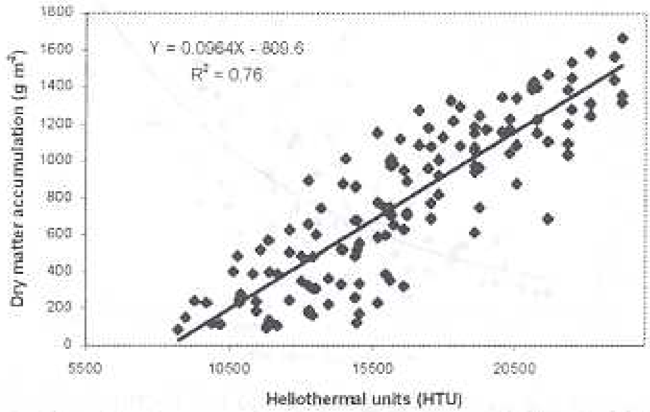

Fig. 5 : Relationship between total dry matter accumulation and heliothermal units in rice

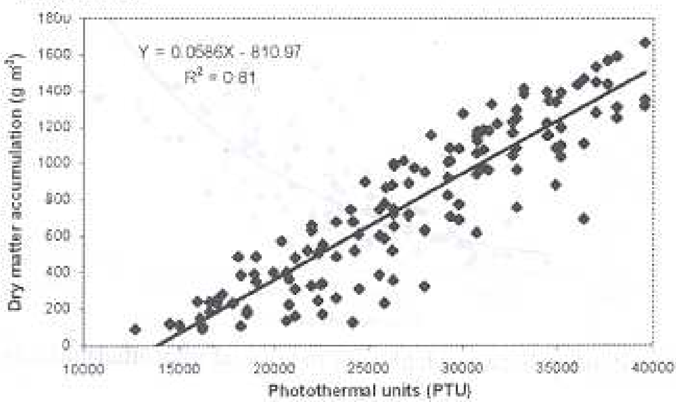

Fig. 6 : Relationship between total dry matter accumulation and photothermal units in rice.

out. However, the exponential regression equations obtained between LAI and three agroclimatic indices and linear regression

equations obtained between TDM and three agroclimatic indices can be a useful tool in predicting periodic LAI development and TDM accumulation of rice using daily information on temperature, photoperiod and sunshine during the crop season. Similar information on developing agroclimatic models based on temperature, photoperiod and daylength for wheat (Hundal *et al.* 1997), mustard (Hundal *et al*, 2003) and soybean (Hundal *et al.* 2003b) have also been reported under Ludhiana conditions.

REFERENCES

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

Hundal, S.S. and Prabhjyot-Kaur 2002. Climate variability at Ludhiana. *J. Res. (PAU)*, **39**(2): 165-76.

Hundal, S. S., Prabhjyot-Kaur and Malikpuri, S.D.S. 2003. 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, R. and Dhaliwal, L.K. 1997. Agro-climatic indices for predicting phenology of wheat (Triticum aestivum) in Punjab. *Indian J. Agril. Sci.*, **67** (6): 265-268.

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

Kar, G. and Chakarvarty, 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.

Singh, R.S., Ramakrishna, Y.S. and Joshi, N.L. 1996. Growth and response of mustard [*Brassica juncea* (L.) Czern & Coss] to irrigation levels in relation to temperature and radiation regimes. *J. Arid Environ.*, **33**: 379-388.

Tripathi, P., Tomar, S.K. and Singh, A.K. 1999. Crop weather models to predict the growth and yield of rice and wheat under rice-wheat cropping system. *In* pp. 285-294 Proceedings (Eds. S.V. Singh *et al*) of the National Workshop on "Dynamic crop Simulation Modelling for Agromet Advisory Service" held at NCMRWF, New Delhi during 4-6 Jan 1999.

Whisler, F.D., Acock, B., Baker, D.N., Fye, R.E., Hodges, H.F., Lambert, J.R., Lemmon, H.E., McKinion, J.M. and Reddy, V.R., 1986. Crop simulation models in agronomic systems. *Advances Agron.*, **40**, 141-208.