

Agroclimatic models for prediction of growth and yield of rice (*Oryza sativa*) under temperate Kashmir conditions*

H SINGH¹, K N SINGH², B HASAN³ and A A KHAN⁴

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir 191 121

Received: 9 February 2009; Accepted: 24 December 2009

Key words: Agroclimatic models, Growing degree-days, Grain yield, Heat-use efficiency, Helio-thermal units, Photo-thermal units, Temperate rice cultivars

Climatic variability is a threat to food production by impacting the performance and management of agricultural systems. Crop potential can be estimated by using biophysical models which range from simple agroclimatic indices to complex models. Dynamic crop growth models are being used extensively for predicting growth and yield of crops, but require large input data and most appropriate in regions, where there is little spatial variability in the environmental factors affect crop growth also some are very complex to use. Therefore, simple models using less input data requirement would be quite useful. Attempts have been made to predict phenology (Dhaliwal *et al.* 2007), leaf area index (Deosthali *et al.* 2005) and total dry matter and growth and yield (Hundal *et al.* 2003) of crops using heat-based indices.

Temperature plays a key role in influencing rice production, growing at an altitude of 1 200 to 2 000 m above the mean sea level in Kashmir valley. Heat-use efficiency, ie efficiency of utilization of heat in terms of dry matter accumulation depends on crop type, genetic factor and sowing time and has great practical application (Rao *et al.* 1999).

Therefore, in the present study an attempt was made to predict the growth and yield of temperate rice with agroclimatic models based on growing degree days, heliothermal units and photothermal units, heat-use efficiency of 4 cultivars of temperate rice was evaluated under varied environments.

The field experiment was conducted during rainy (*khariif*) season of 2004 and 2005 at Shalimar campus of Sher-e-Kashmir University of Agricultural Sciences and Technology,

Short note*

Based on a part of Ph D thesis of the first author submitted to the SKUAST (K) during 2007.

¹Deputy Director (Trg.) (e mail: harinder06@rediffmail.com), KVK, PAU, Fatehgarh Sahib, Punjab 140406, ²Associate Director Extension, ³Dean, Faculty of Agriculture, ⁴Professor, Department of Statistics, Aligarh Muslim University, Aligarh.

Srinagar, Jammu and Kashmir (35°–52 N latitude and 74° 89 E longitude, 1 587 m above mean sea level). The soil was silty clay loam (Hapludalf) with 0.9% organic carbon and available N, P and K of 280, 19.1, 268 kg/ha, respectively. Treatments comprised 3 transplanting dates (25 May, 10 June, 25 June) and 4 rice cultivars ('Jhelum', 'K 39', 'Shalimar rice 1' and 'China 1007') randomized in split-plot design with 3 replications. Three seedlings of 32 days old were transplanted at a spacing of 15 cm×15 cm on the defined dates of transplanting. A uniform dose of 120 kg N, 60 kg P₂O₅, and 45 kg K₂O and 15 kg ZnSO₄/ha was applied in all the treatments. All the P, K and Zn and half of N were applied basally, whereas the remaining N was applied in 2 splits at mid-tillering and panicle-initiation stages. Water depth was maintained±5 cm throughout growth period except at mid-tillering and panicle-initiation stage to facilitate top-dressing of N and soil aeration. Plant samples were collected periodically at 15–day intervals. Dry matter was taken from 5 hills, clipped randomly from penultimate row of each plot and determined after oven drying at 70°C to constant weight. Leaf area was recorded *in situ* by canopy analyzer Accupar LP-80. Three agroclimatic indices, namely growing degree-days, helio-thermal units and photo-thermal units were calculated. Growing degree-days (GDD) were determined as per Nuttonson (1955).

Growing degree-days, helio-thermal units and photo-thermal units were accumulated from the date of transplanting to give accumulated indices.

It is evident from scatter plot matrix that in most of the cases there is non-linear relationship between agroclimatic indices and yield, dry matter and leaf area index (Fig 1). Thus non-linear models are fitted for this data using *nls* function of R (R development core team 2008). Leaf area index and dry matter accumulation were related with accumulated growing degree-days, helio-thermal units and photo-thermal units to find the best-fit relationship. The potential climate change certainly has impact on agroclimatic indices (Bootsma *et al.* 2005). As such predictions were also

made with different values of agroclimatic indices using the function *predict* of language for statistical computing (RDCT 2008).

Accumulated agroclimatic indices, ie growing degree-days, helio-thermal units and photo-thermal units, computed for temperate rice cultivars under different treatments from sowing to physiological maturity are given in Table 1. In early-sown cultivars, higher agroclimatic indices were required for the crop to attain maturity. However, when dates of sowing were delayed, lower agroclimatic indices were needed by temperate rice to attain physiological maturity. Among the 4 cultivars, ‘Shalimar rice 1’ and ‘China 1007’ required higher agroclimatic indices to attain physiological maturity than ‘Jhelum’ and ‘K 39’.

Accumulated growing degree-days, total dry matter accumulated at physiological maturity, grain yield at harvest and heat-use efficiency for different treatments are given in Table 1. In general earlier transplanted rice availed more growing degree-days and accumulated more dry matter than the later transplanted crop irrespective of cultivar type.

Dry matter accumulation was significantly reduced in late-sown cultivars which resulted in significantly reduction in grain yields. The significantly highest heat-use efficiency of 13.2 kg/ha/°C day and 5.88 kg/ha/°C day was recorded for dry matter and grain yield, respectively, when the crop was transplanted on 25 May. In most cases, however, heat use efficiency decreased with delay in transplanting. ‘Jhelum’ and ‘K 39’ significantly performed better than ‘Shalimar rice 1’ and ‘China 1007’ in terms of heat-use efficiency for both dry matter accumulation and grain yield.

The regression relationships obtained between maximum leaf area index as dependent variable and growing degree-days or photo-thermal units or helio-thermal units as independent variable up to maximum leaf area development based on data of 2 crop seasons and 4 cultivars are shown below. Significant exponential relationship between leaf area index and growing degree-days or helio-thermal units or photo-thermal units was observed (Table 2) while it is evident from scatter plot matrix that there is non-linearity of the response of leaf area index to agroclimatic indices (Fig 1).

Table 1 Agroclimatic indices and heat-use efficiency for 4 temperate rice cultivars sown on different dates during 2 crop seasons

Crop year	Cultivar	Date of transplanting	Accumulated GDD (° day)	Accumulated HTU (° day hour)	Accumulated PTU (° day hour)	Total dry matter (kg/ha)	Grain yield (kg/ha)	Dry matter HUE (kg/ha ° day)	Grain yield HUE (kg/ha/° day)	
2004	‘Jhelum’	25 May	1 525	11 639	20 325	18 710	8 380	12.27	5.49	
		10 June	1 511	11 543	19 878	16 680	7 620	11.03	5.04	
		25 June	1 402	10 737	18 090	14 080	6 030	10.04	4.30	
	‘K 39’	25 May	1 525	11 639	20 325	18 890	8 430	12.39	5.53	
		10 June	1 511	11 543	19 878	17 380	7 490	11.50	4.95	
		25 June	1 402	10 737	18 090	13 590	5 710	9.69	4.07	
	‘Shalimar rice 1’	25 May	1 575	12 098	20 937	17 250	7 630	10.95	4.84	
		10 June	1 541	11 739	20 233	17 310	6 950	11.23	4.51	
		25 June	1 420	11 035	18 393	14 010	5 340	9.86	3.76	
	‘China 1007’	25 May	1 575	12 098	20 937	17 250	7 350	10.95	4.67	
		10 June	1 541	11 739	20 233	16 780	6 780	10.88	4.40	
		25 June	1 420	11 035	18 393	14 290	4 820	10.06	3.39	
	CD (<i>P</i> =0.05)									
	Transplanting date						1 101	484	0.90	0.32
	Varieties						931	393	0.78	0.23
2005	‘Jhelum’	25 May	1 540	12 789	20 452	20 330	9 050	13.30	5.88	
		10 June	1 531	12 914	20 395	18 250	8 280	11.92	5.41	
		25 June	1 467	12 152	18 929	14 550	6 020	9.92	4.10	
	‘K 39’	25 May	1 540	12 789	20 452	20 380	9 060	13.23	5.88	
		10 June	1 531	13 017	20 395	18 470	8 040	11.98	5.21	
		25 June	1 467	12 152	18 929	14 770	5 880	10.07	4.01	
	‘Shalimar rice 1’	25 May	1 596	13 307	20 995	18 490	8 240	11.58	5.16	
		10 June	1 593	13 477	21 100	19 010	7 520	11.93	4.72	
		25 June	1 502	12 298	19 189	17 190	5 720	11.44	3.81	
	‘China 1007’	25 May	1 596	13 307	20 995	19 040	8 150	11.93	5.11	
		10 June	1 588	13 463	21 219	17 730	7 260	11.06	4.53	
		25 June	1 509	12 381	19 326	16 500	5 370	10.93	3.56	
	CD (<i>P</i> =0.05)									
	Transplanting date						1 204	520	1.0	0.38
	Varieties						995	421	0.83	0.25

GDD, Growing degree days; HTU, helio-thermal units; PTU, photo-thermal units

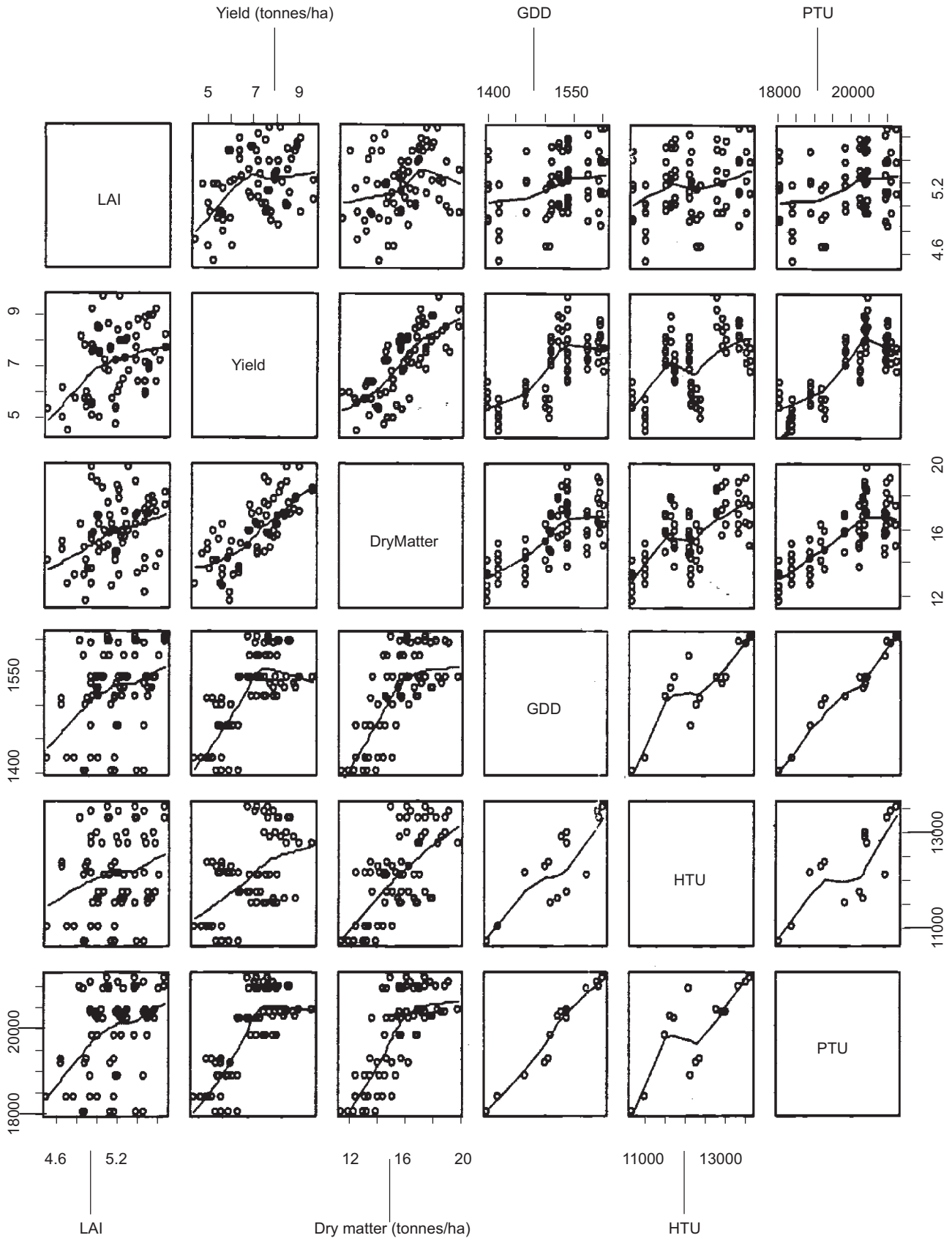


Fig 1 Scatter plot matrix between different parameters

$$\text{LAI} = 3.45 e^{0.00026 \text{ GDD}}$$

$$\text{LAI} = 4.40 e^{0.000013 \text{ HTU}}$$

$$\text{LAI} = 3.61 e^{0.000018 \text{ PTU}}$$

The regression equation obtained between total dry matter (TDM) accumulation in above ground parts as dependent variable and growing degree-days or helio-thermal units or photo-thermal units as independent variable based on data of 2 crop seasons and 4 cultivars are shown below.

$$\text{TDM} = 3.69 * 10^{-06} \text{ GDD}^{2.084}$$

$$\text{TDM} = 4.79 * 10^{-04} \text{ HTU}^{1.105}$$

$$\text{TDM} = 4.19 * 10^{-07} \text{ PTU}^{1.762}$$

Significant power function relationship between total dry matter and growing degree-days or helio-thermal units or photo-thermal units were observed in temperate rice (Table 2).

The regression relationships obtained between grain yield (GY) as dependent variable and growing degree-days or photo-thermal units or helio-thermal units as independent variable based on data of 2 crop seasons and 4 cultivars are shown below. Significant power function relationship between grain yield and growing degree-days or helio-thermal units or photo-thermal units were observed in temperate rice (Table 2).

$$\text{GY} = 1.97 * 10^{-09} \text{ GDD}^{3.004}$$

$$\text{GY} = 3.10 * 10^{-05} \text{ HTU}^{1.312}$$

$$\text{GY} = 9.54 * 10^{-12} \text{ PTU}^{2.761}$$

The above models were also used to predict the total dry matter and yield of rice under different values of agroclimatic indices. The results indicated that a substantial increase in GDD, HTU and PTU values increase the dry matter and yield of temperate rice.

The results revealed that the exponential regression

equation obtained between leaf area index and agroclimatic indices and power regression equations between total dry matter and grain yield with agroclimatic indices can be a useful tool in predicting leaf area index, total dry matter and grain yield of temperate rice using daily information on temperature, photoperiod and sunshine duration during the crop season. In future the possibility of higher values of agroclimatic indices due to change in climate may likely increase the yield of temperate rice.

SUMMARY

Three agroclimatic models based on growing degree-days, helio-thermal units, and photo-thermal units were determined at Srinagar during 2004 and 2005 for prediction of growth and yield of 4 cultivars ('Jhelum', 'K 39', 'Shalimar rice 1' and 'China 1007') of rice (*Oryza sativa* L.) under 3 transplanting dates (25 May, 10 June and 25 June). Heat-use efficiency for production of biomass and grain yield was also characterized for all the cultivars. The highest heat-use efficiency of 13.2 kg/ha/°C day and 5.88 kg/ha/°C day was recorded for dry matter and grain yield, respectively when the crop was transplanted on 25 May. Leaf area development revealed an exponential relationship, while dry matter and grain yield showed a power function relationship with the 3 agroclimatic indices growing degree-days, helio-thermal units, and photo-thermal units. Grain yield was higher in first transplanting date, followed by second and third date of transplanting. The agroclimatic prediction models can be used to estimate crop growth and yields of rice in temperate conditions of Kashmir valley.

REFERENCES

Bootsma A, Gameda S and Mckenney D W. 2005. Impacts of potential climate change on selected agroclimatic indices in Atlantic Canada. *Canadian Journal Soil Science* **85**: 329–43.

Deosthali V, Salunke C and Akmanchi A. 2005. Relationship of LAI and Biomass of soyabean with agroclimatic indices. *Journal of Agrometeorology* **7**(2): 249–54.

Dhaliwal L K, Hundal S S and Chahal S K. 2007. Agroclimatic indices of Indian mustard (*Brassica juncea*) under Punjab conditions. *Indian Journal of Agricultural Sciences* **77**(2): 82–91.

Hundal S S, Singh Harpreet, Kaur Prabhjot and Dhaliwal L K. 2003. Agroclimatic models for growth and yield of soyabean (*Glycine max*). *Indian Journal of Agricultural Sciences* **73**(12): 668–70.

Nuttonson M Y. 1955. *Wheat Climate Relationships and Use of Phenology in Ascertaining the Thermal and Photothermal Requirements of Wheat*. American Institute of Crop Ecology, Washington DC 388 pp.

RDCT. 2008. R: A language and environment for statistical computing. R Foundation for statistical Computing, Vienna, Austria. <http://www.R-project.org>

Rao V U M, Singh D and Singh R. 1999. Heat-use efficiency of winter crops in Haryana. *Journal of Agrometeorology* **1** (2): 143–8.

Table 2 Statistical analysis of parameters in the models

Relationship	Parameter	Standard error	t value
LAI×GDD	LAI	4.99e-01	6.91***
	GDD	9.52e-05	2.80**
LAI×HTU	LAI	3.72e-01	11.81***
	HTU	6.94e-06	1.92.
LAI×PTU	LAI	4.12e-01	8.76***
	PTU	5.71e-06	3.16**
TDM×GDD	TDM	7.49e-06	0.49
	GDD	2.77e-01	7.53***
TDM×HTU	TDM	7.27e-04	0.66
	HTU	1.61e-01	6.86***
TDM×PTU	TDM	8.68e-07	0.48
	PTU	2.10e-01	8.42***
GY×GDD	GY	6.33e-09	0.31
	GDD	4.37e-01	6.87***
GY×HTU	GY	7.88e-05	0.39
	HTU	2.70e-01	4.86***
GY×PTU	GY	2.94e-11	0.32
	PTU	3.10e-01	8.89***

Number of observations in each case was 72

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1