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Crop specific requirement of growing degree days and agrometeorological indices in rice growing zones

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सार – इस शोध पत्र मे धान की फसल के लिए ताप इकाई एवं भिन्न–भिन्न कृषि मौसम विज्ञान संबंधी सूचनाओं के स्थानिक और कालिक वितरण का अध्ययन किया गया है। धान की खेती किए जाने वाले छह क्षेत्रों जैसे कैनिंग (गांगेय क्षेत्र का निचला भाग) विक्रमगंज एवं वाराणासी (मध्य गांगेय क्षेत्र) लुधियाना (गांगेय पार क्षेत्र), राँची, श्यामखुण्टा (पूर्वी पठार एवं पहाड़ियों में) अन्नामलाई नगर (पूर्वी तट के मैदानी तथा पर्वतीय क्षेत्र) और पट्टम्बी (पश्चिमी मैदानी एवं घाट क्षेत्र) में से आठ ई. टी. स्टेशनों का चयन किया गया है। इस शोध में फसल को उगाने के लिए ग्यारह चरणों जैसे :– बीज का अंकुरण, धान का बिचडा तैयार करना, रोपाई, खरपतवार निकालना, निराई, लैग फेज, फूल आने की प्रकिया का आरंभ, धान में फूल का आना, दाना बनना, दाने का पकना और कटाई का पता लगाया गया है। प्रत्येक चरण के विकास की अवधि में अलग अलग स्टेशनों पर काफी भिन्नता पाई गई है। विगत पाँच वर्षों के उपलब्ध आँकडों से फसल के विकास के विभिन्न चरणों के दैनिक आँकडें सग्रहित किए गए है और प्राप्त किए गए प्राचालों जैसे :– फसल के लिए आवश्यक ताप इकाई, कृषि जलवायविक वर्षा सूचकांक (ए. आर. आई.), पैदावार की नमी सूचकांक (वाई. एम. आई.), शुष्कता सूचकांक (ए. आई.) के लिए इनके औसत मान की गणना की गई है। इस शोध से यह पता चला है कि धान की फसल के लिए कुल तापीय डिग्री–दिवसों की आवश्यकताओं में भिन्नता 1706 डिग्री–दिवस (राँची में) से 2815 डिग्री दिवस (श्यामखुण्टा में) के बीच पाई गई है। ऐसा पाया गया है कि निराई के चरण में तापीय आवश्यकता आरंभ में सबसे अधिक होती है (जो कुल आवश्यकता का 16.7 प्रतिशत होती है।) कृषि जलवायविक सूचकांक के मान प्रायः 100 प्रतिशत से अधिक होते हैं। पैदावार के नमी सूचकांक के औसत मान में भिन्नता 477 मि. मी. (बिक्रमगंज में) से 1523 मि. मी. (पट्टम्बी में) के बीच पाई गई है। इन मानों से यह पता चला है कि निराई की अवस्था में तापीय आवश्यता सबसे अधिक होती है। शुष्कता सूचकांक मानों से पता चला है कि विकास की आरंभिक अवस्था में सामान्य शुष्कता होती है जो फसल के विकास के अनुसार बढ़ती जाती है।

ABSTRACT. The spatial and temporal distributions of heat unit and various agrometeorological indices for the rice crop, are studied in this paper. Eight ET – stations were selected from six rice growing zones, *viz.*, Canning (in lower Gangetic plains), Bikramganj and Varanasi (in middle Gangetic plains), Ludhiana (in trans Gangetic plains), Ranchi, Shymakhunta (in eastern plateau and hills), Annamalai Nagar (in east coast plains and hill region) and Pattambi (in western plains and ghat region). Eleven crop growth stages were identified for this study, *viz*., germination, nursery seedling, transplanting, tillering, active tillering, lag phase, panicle initiation, flowering, grain formation, grain maturity and harvesting, the duration of each of the growth stages varied widely, station wise. Daily data were collected growth stagewise for latest available five years and the mean values were computed for the derived parameters, *viz*., the crop requirements of heat unit, agroclimatic rainfall index (ARI), yield moisture index (YMI), aridity index (AI). The study revealed that for rice crop the total degree days requirement varied from 1706 degree – days (at Ranchi) to 2815 degree – days (at Shymakhunta). It showed primary peak (with 16.7 % of total requirement) at active tillering stage. The ARI values were mostly higher than 100 per cent. The mean YMI values varied widely from 477 mm (at Bikramganj) to 1523 mm (at Pattambi). The values showed main peak at active tillering stage. The AI values showed moderate aridity at early growth stages, which increased at advanced crop growth stages.

Key words – Heat unit, Growing degree days, Agrometeorological indices, ARI, YMI, AI, Growth stages, Active tillering, Lag phase.

1. Introduction

Rice (*Oryza sativa* L.) is the most important food crop in tropics and subtropics. It is a semi-aquatic but heat loving plant with high water requirement. In India it is the most important rainfed kharif crop, though it can be grown throughout the year. In the country it is grown in most of the States, *viz*., Andhra Pradesh, West Bengal, Bihar, Assam, Uttar Pradesh, Orissa, Tamil Nadu, Kerala, Maharashtra, Karnataka, Madhya Pradesh and Punjab. As per the estimate of Directorate of Rice Development, Patna, during last year the crop (during both kharif and rabi seasons) was grown in 449.72 lac hectare area with production of 894.76 lac tonnes.

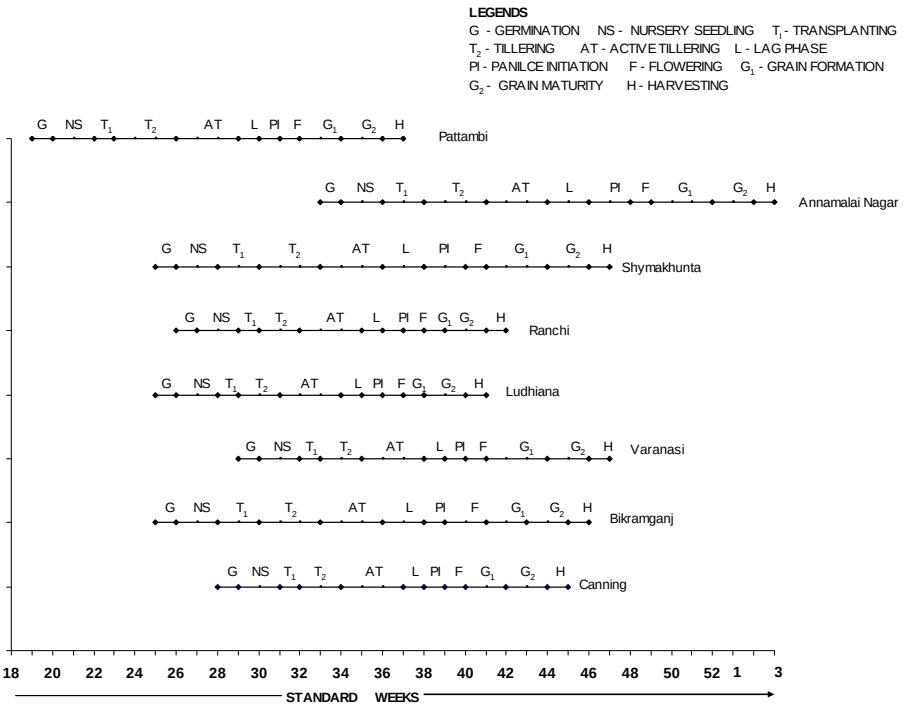


Fig. 1. Mean duration and growth stages of rice crop at different ET-stations

The crop duration varies widely from 3½ to 5 months depending on seasons, varieties and soil type. The growth stages identified for the rice crop are: germination, nursery seedling, transplanting, tillering, active tillering, lag phase, panicle initiation, flowering, grain formation, grain maturity and harvesting, which are found critical in their specific water demand. Though, flowering and grain formation stages are very much sensitive to water deficiency. The crop variety, soil type and weather parameters of that region, governs the duration of each of the growth stages.

The optimum range of air temperature for floral initiation is 25 – 30° C by day and 20- 25° C by night and for successful anthesis the optimum temperature is 30° C. The root, shoot growth of rice crop is also governed by temperature (Owen 1971). Robertson and De Weille (1973) opined that the duration of tillering period is sensitive to light and temperature factors. Evapotranspiration of rice (when less than maximum ET demand) is linearly related to yield and inversely related to spikelet sterility (Cruz and O' Toole 1984). Considering these studies by various workers, the present work has been undertaken to study both the spatial and temporal distributions of heat unit and various agrometeorological indices as computed through different meteorological parameters fluctuating in different locations. The computed values of heat unit, agroclimatic rainfall index (ARI), yield moisture index (YMI), aridity index (AI) are summarized and critically analysed to get an idea of rice crop condition in various locations.

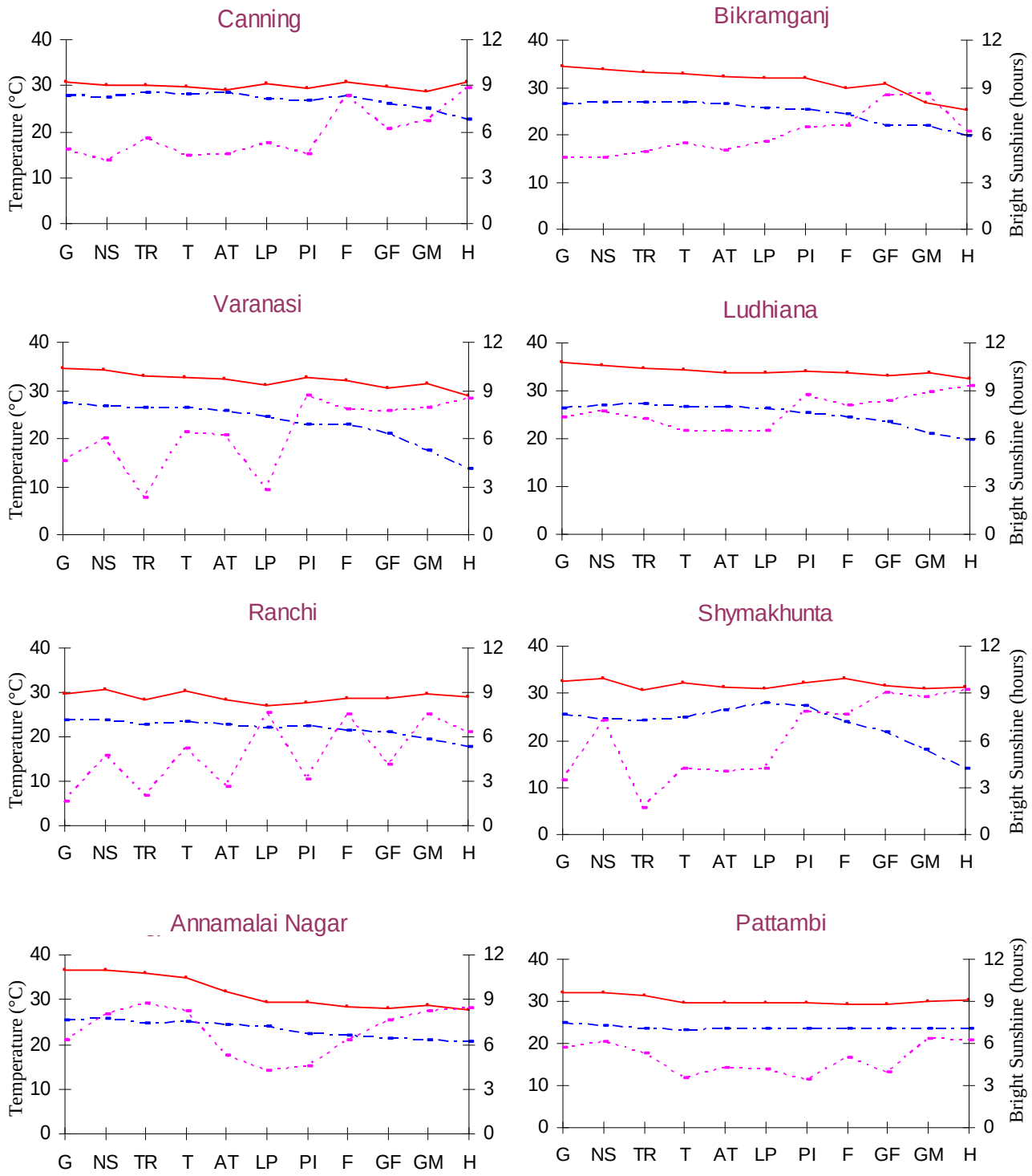
2. Methodology

2.1. *Selection of zones*

Eight rice growing ET stations, *viz*., Canning (in lower Gangetic plains), Bikramganj and Varanasi (in middle Gangetic plains), Ludhiana (in trans Gangetic plains), Ranchi and Shymakhunta (in eastern plateau and hills), Annamalai Nagar (in east coast plains and hill region) and Pattambi (in western plains and ghat region) were selected from six zones. The zoning of the stations is according to Planning Commission, Govt. of India, 1989 (Anonymous 1989). The crop is mainly rainfed in all stations except Ludhiana and Bikramganj, where supplementary irrigation is applied.

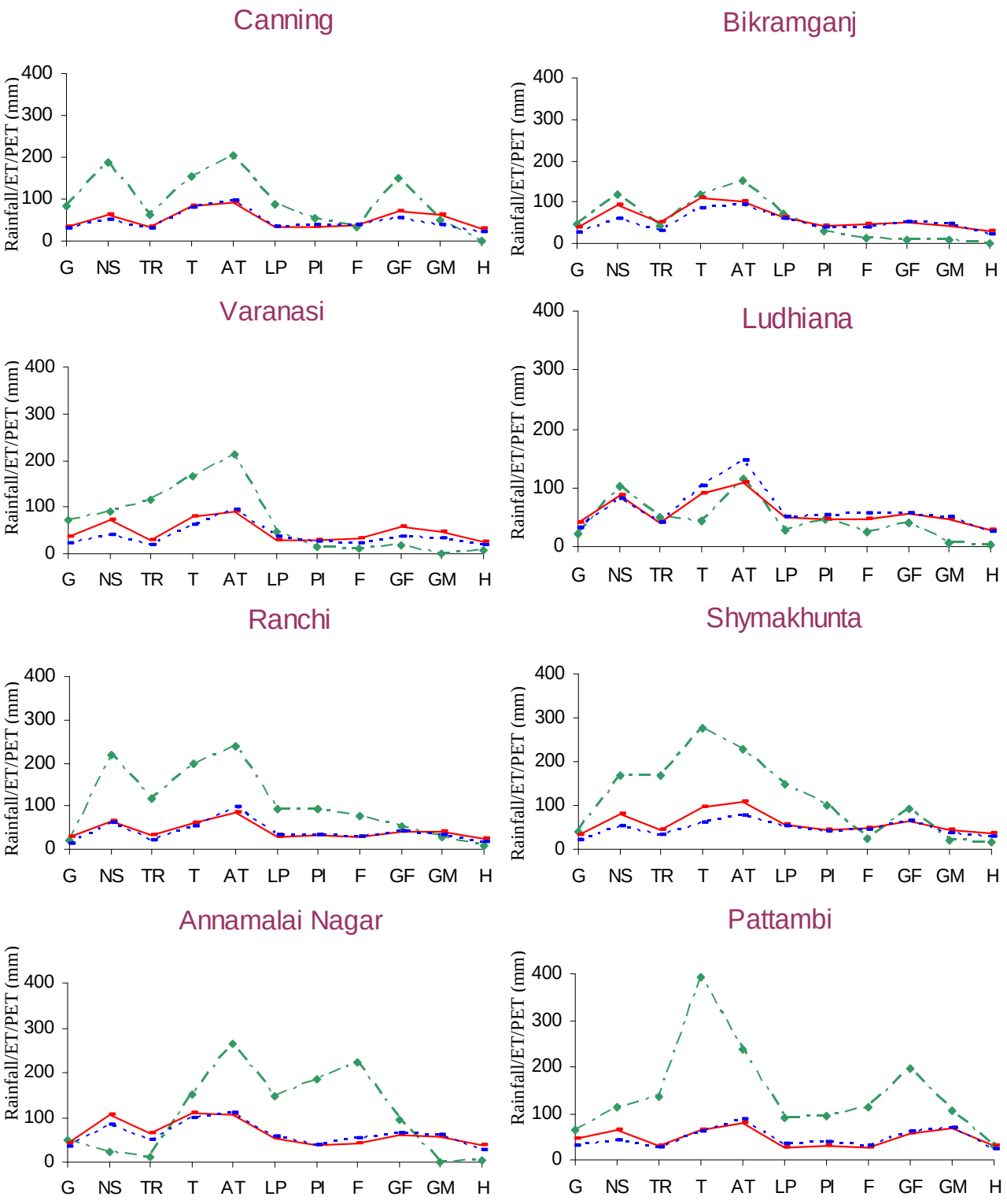
2.2. *Data*

The mean growing period (in standard weeks) of each of the eleven critical growth stages, *viz*., germination, nursery seedling, transplanting, tillering, active tillering, lag phase, panicle initiation, flowering, grain formation, grain maturity and harvesting of rice crop are determined and are presented in Fig. 1. Daily data on rainfall,



LEGENDS
____Max. Temperature, _ _ _ _ Min. Temperature, ------- SSH (Bright Sunshine hours),
G - Germination, NS - Nursery seedling, TR - Transplanting, T - Tillering, AT - Active tillering, LP - Lag phase,
PI - Panicle initiation, F - Flowering, GF - Grain formation, GM - Grain maturity, H – Harvesting

Figs. 2(a). The maximum, minimum temperatures and bright sunshine hours at various growth stages of rice crop at different locations



LEGENDS

_ _ _ _ _ _Rainfall, _____ Potential evapotranspiration, ------- Actual evapotranspiration

G - Germination, NS - Nursery seedling , TR - Transplanting, T - Tillering, AT - Active tillering, LP- Lag phase, PI - Panicle initiation, F- Flowering, GF - Grain formation, GM - Grain maturity, H - Harvesting

Figs. 2(b). Rainfall, potential evapotranspiration and evapotranspiration at various growth stages of rice crop at different locations

TABLE 1

Growth stage wise mean heat unit requirement (degree days) of rice crop at different ET –stations

Crop growth stages	ET - Stations							
	Canning	Bikramganj	Varanasi	Ludhiana	Ranchi	Shymakhunta	Annamalai Nagar	Pattambi
Germination	134.1	142.8	147.0	125.7	83.3	133.0	147.3	130.2
Nursery seedling	261.1	367.2	287.7	295.4	240.8	338.4	379.8	254.8
Transplanting	135.5	200.0	137.2	146.7	109.2	175.0	203.0	121.5
Tillering	323.0	416.9	332.3	329.6	234.5	388.5	418.9	280.5
Active tillering	376.0	406.3	379.0	404.0	309.0	468.8	451.3	332.0
Lag phase	130.6	263.2	124.6	139.3	101.5	273.0	233.8	116.2
Panicle initiation	125.7	186.0	123.5	137.5	105.0	196.5	157.5	116.2
Flowering	134.4	188.1	140.0	133.7	106.1	204.1	166.7	114.5
Grain formation	269.3	227.5	251.2	219.6	162.8	283.1	234.4	229.6
Grain maturity	234.5	200.9	201.6	189.7	160.1	202.3	206.5	235.2
Harvesting	115.9	125.0	113.0	112.7	93.8	151.8	155.1	118.3
Total	2240.1	2723.9	2237.1	2233.9	1706.1	2814.5	2754.3	2049.0

minimum and maximum temperatures, bright hours of sunshine and actual evapotranspiration were collected from all the eight stations for five years and the mean values were obtained for each of the growth stages. These data were used to compute the derived parameters, *viz.*, heat unit requirement and for evaluation of different agrometeorological indices at different growth stages of rice crop. Mean minimum & maximum temperatures, bright sunshine hours, rainfall, actual and potential evapotranspiration at various growth stages of rice crop for all the stations studied are presented in Figs. 2(a&b), respectively.

2.3. *Heat unit*

The growing degree days or heat unit is determined by the following formula:

$$\mathrm{GDD} = \sum_{i=1}^{n} \left(\frac{T_{\max} + T_{\min}}{2} - T_t \right) \qquad (1)$$

where, $\frac{T_{\max} + T_{\min}}{2.0}$ is the average daily temperature obtained from Fig. 2(a) and T_t is the minimum threshold (base) temperature (10° C for rice) below which there is no crop growth (Kakde 1985). However, the basic assumption for this computation is the linear and direct relationship between temperature and growth of plant. The computed daily heat unit values were summed up, growth stage wise, for all the stations for different years and the mean values are computed and are presented (Table 1).

2.4. *Agrometeorological indices*

Data of all the ET – stations are utilized for computation of different indices, *viz.*, agroclimatic rainfall index (ARI), yield moisture index (YMI) and aridity index (AI).

2.4.1. *Agroclimatic rainfall index (ARI)*

Nieuwolt (1981) proposed agroclimatic rainfall index (ARI), which is given by:

$$\mathrm{ARI} = \frac{\mathrm{P}}{\mathrm{PET}} \times 100 \qquad (2)$$

where, P and PET are the growth stage-wise rainfall (mm) and potential evapotranspiration (mm) respectively, obtained from Fig. 2(b). The computed values for different years are used for computation of mean ARI and are presented in Table 2.

2.4.2. *Yield moisture index (YMI)*

The YMI as stated by Steyaert *et al*. (1981) was determined as follows:

$$\left(\mathrm{YMI}\right)_j = \sum_{i=1}^{n} C_{ij} P_i \qquad (3)$$

where, $(\mathrm{YMI})_j$ is the yield moisture index for the j^{th} crop. P_i is the rainfall (mm) during the i^{th} crop growth stage and C_{ij} is the appropriate crop coefficient (*i.e*., the ratio of actual to potential evapotranspiration) as obtained

TABLE 2

Mean agroclimatic rainfall index (ARI) at various growth stages of rice crop at different ET – stations

Crop growth stages	ET - Stations							
	Canning	Bikramganj	Varanasi	Ludhiana	Ranchi	Shymakhunta	Annamalai Nagar	Pattambi
Germination	261.6	112.9	191.2	52.3	79.9	136.2	122.1	133.4
Nursery seedling	298.1	126.0	123.4	115.5	334.2	207.8	22.7	176.3
Transplanting	186.4	82.0	377.0	119.7	375.8	394.5	15.8	444.6
Tillering	185.9	105.4	204.6	48.1	340.7	285.7	138.5	602.8
Active tillering	226.0	153.7	231.4	106.0	283.3	212.5	250.3	292.6
Lag phase	275.2	119.1	157.7	58.7	324.7	268.4	269.0	333.5
Panicle initiation	173.1	72.5	50.3	101.7	291.6	232.1	507.1	330.6
Flowering	89.4	31.8	36.7	51.4	252.5	52.2	547.8	406.2
Grain formation	213.7	16.2	33.4	71.8	124.3	144.5	155.5	338.3
Grain maturity	81.3	17.6	3.93	14.0	69.9	42.8	2.92	160.9
Harvesting	2.9	0.0	28.7	7.5	26.3	42.5	5.1	98.7

from Fig. 2(b). The crop coefficient as computed for rice crop at different growth stages in various agroclimatic zones were used. Computed YMI values for different years are used for computation of mean and are presented in Table 3.

2.4.3. *Aridity index (AI)*

The AI, based on the values of water deficiency at various growth stages of rice, as proposed by Thornthwaite (1948) is computed by the formula:

$$AI = \frac{PET - AET}{PET} \times 100 \qquad (4)$$

where, PET and AET are the potential and actual evapotranspiration (mm) respectively. The AI values are presented in Table 4.

3. Results and discussion

The different parameters computed, *viz.*, heat unit, agroclimatic rainfall index (ARI), yield moisture index (YMI), aridity index (AI), their spatial and temporal distributions are discussed in this part.

3.1. *Growing degree days or heat unit*

Rice crop growth stagewise distribution of mean heat unit requirement as varied in different locations are presented in Table 2. During the growing period of rice crop the mean total heat unit requirement was around 2345 degree-days (the values ranged from as low as 1706 degree-days at Ranchi to as high as 2815 degree-days at Shymakhunta). The mean degree days requirement for most of the stations showed primary peak at active tillering stage (390.8 degree-days *i.e.*, 16.7% of total heat unit requirement), secondary peak at nursery seedling (303.2 degree-days *i.e.*, 12.9 % of total heat unit requirement) and tertiary peak observed at grain formation stage (234.7 degree-days *i.e.*, 10.0% of total heat unit requirement). Similarly all the stations under study showed initial low values at harvesting stage and at germination stage followed by dip at panicle initiation stage. In between dips were also observed at flowering, lag phase and at transplanting stages.

Kakde (1985) reported that every crop requires certain definite quantities of heat unit for development of each of the growth stages and final maturity. In case of wheat crop, Kashyapi and Das 1999, observed mainly two peaks at different crop growth stages. Gillespie (1985) opined that the computed heat unit is an important tool in efficient pest management. It correlates very well with stages of insect pest development and the threshold temperature for pest development is usually found under controlled environment studies. Degree – days can be used to decide when a pest has reached a life stage; where control becomes easier in combination with field visit by trained personnel.

3.2. *Agrometeorological indices*

The computed agrometeorological indices, *viz.*, ARI, YMI and AI are discussed hereunder.

3.2.1. *Agroclimatic rainfall index (ARI)*

During kharif season in most of the stations under study, recorded higher rainfall as compared to the PET

TABLE 3

Mean yield moisture index (YMI in mm) at the end of various growth stages of rice at different ET – stations

Crop growth stages	ET - Stations							
	Canning	Bikramganj	Varanasi	Ludhiana	Ranchi	Shymakhunta	Annamalai Nagar	Pattambi
Germination	71.8	27.6	44.0	15.7	9.6	28.0	41.3	41.7
Nursery seedling	152.1	74.2	51.0	94.8	200.7	109.5	18.7	71.6
Transplanting	52.9	23.9	69.0	48.8	74.3	123.2	7.9	112.5
Tillering	147.0	88.0	128.6	49.2	178.0	168.2	133.5	361.6
Active tillering	215.6	140.9	220.0	155.6	277.7	165.3	276.8	251.2
Lag phase	95.1	67.7	55.5	29.9	102.5	143.5	148.4	110.0
Panicle initiation	63.7	26.7	13.1	52.4	98.9	96.5	199.7	118.3
Flowering	32.8	12.5	8.4	27.8	70.5	24.2	284.7	122.2
Grain formation	113.3	8.2	11.8	40.9	49.5	91.0	100.7	200.3
Grain maturity	29.1	8.1	1.3	6.8	22.0	15.1	1.7	111.6
Harvesting	0.6	0.0	5.2	1.8	4.4	11.9	1.4	22.2
Total	974.0	477.8	607.9	523.7	1088.1	976.4	1214.8	1523.2

TABLE 4

Mean aridity index (AI) at various growth stages (in percent) of rice crop at different ET – stations

Crop growth stages	ET - Stations								Mean
	Canning	Bikramganj	Varanasi	Ludhiana	Ranchi	Shymakhunta	Annamalai Nagar	Pattambi	(growth stage wise)
Germination	14.6	38.3	39.3	25.3	55.2	32.6	16.4	24.0	32.0
Nursery seedling	19.2	36.2	43.0	7.3	7.5	35.3	21.1	39.2	26.1
Transplanting	18.2	43.0	39.7	2.4	37.3	26.3	22.9	52.9	30.3
Tillering	4.9	24.1	22.3	0.0	10.7	39.5	11.7	40.5	19.2
Active tillering	0.0	7.9	0.0	0.0	0.0	27.5	0.0	0.0	4.4
Lag phase	0.0	7.8	0.0	0.0	0.0	4.3	0.0	0.0	1.5
Panicle initiation	0.0	11.4	13.4	0.0	0.0	4.1	0.0	0.0	3.6
Flowering	0.0	12.1	32.5	0.0	5.7	1.5	0.0	0.0	6.5
Grain formation	24.9	2.3	40.3	0.0	5.5	1.3	0.0	0.0	9.3
Grain maturity	42.6	0.0	26.2	0.0	24.3	22.2	0.0	0.0	3.1
Harvesting	27.4	19.8	30.6	12.9	35.9	23.0	25.6	28.8	25.5

demand at various crop growth stages. Hence, the values of index were mostly higher than 1.0 (Table 3). However, stations, *viz*., Bikramganj, Varanasi recorded low values (*i.e*., P < PET) from panicle initiation stage onward, Ludhiana recorded low values from flowering stage onward, while rest of the stations mostly recorded low values from grain maturity stage onward. The values were the highest at each of the growth stages at Pattambi followed by Ranchi, while values were the lowest at Ludhiana followed by Bikramganj. During kharif season due to monsoon rainfall mainly the values of index were more than 1.0. Similar type of result was obtained by Kashyapi and Das (1999) for wheat crop.

3.2.2. *Yield moisture index (YMI)*

The mean yield moisture index values (Table 4) showed main peak at active tillering stage for most of the stations, while Shymakhunta and Pattambi recorded the highest peak at tillering stage but Annamalai Nagar recorded the same at flowering stage. Stations, *viz.*, Canning, Bikramganj and Ludhiana recorded 3 peaks, while most of the stations recorded 2 peaks. The YMI is the product of crop coefficient to precipitation, hence it reached the main peak at active tillering or tillering stage. The total YMI at different stations varied widely from 477 mm at Bikramganj to 1523 mm at Pattambi. Prasad and

Datar (1990) opined that YMI is a good drought indicator. During kharif season all the stations recorded medium to high mean YMI indicating no drought at those stations during the study period.

3.2.3. *Aridity index (AI)*

Growth stage wise mean aridity index (AI) values as obtained at various growth stages of rice crop at different ET – stations are presented in Table 5. The general trend observed was moderate aridity at early growth stages of the rice crop (upto transplanting or tillering stage), which reduced during active tillering to flowering or grain formation stages, while the values increased at later, advanced growth stages for most of the stations. Canning (from active tillering to flowering stages), Varanasi (from active tillering to lag phase), Ludhiana (from tillering to grain formation stages), Anamalai Nagar and Pattambi (from active tillering to grain maturity stages) observed no aridity in rice crop during some stages of crop growth period.

3.2.4. *Study of aridity index (AI) versus agroclimatic rainfall index (ARI)*

The study of correlation coefficient (*r*) between AI and ARI revealed that for rice crop for most of the stations studied the values were negative. The correlation coefficient values were high for Ranchi (-0.51) and Annamalai Nagar (-0.65). The highest correlation observed at Annamalai Nagar was found significant at 5% level of significance.

4. Conclusions

The study on rice crop specific requirement of growing degree days revealed the following conclusions.

(*i*) The mean total growing degree days requirement of the rice crop was around 2345 degree days. The total requirement ranged between 1706 degree days at Ranchi to 2815 degree days at Shymakhunta.

(*ii*) The mean degree days requirement for most of the stations studied showed the primary peak (with 16.7% of total requirement) at active tillering stage followed by other peaks at nursery seedling and grain formation stages. However, during growing period of rice crop, dips were observed mainly at panicle initiation stage and also at flowering, lag phase and transplanting stages, which may be due to rainfall pattern, cloudiness etc.

(*iii*) During monsoon period ARI values were mostly higher than 1.0. However, at some growth stages of rice, stations, *viz*., Bikramganj, Varanasi recorded low values from panicle initiation stage onward, Ludhiana recorded low values from flowering stage onward, while rest of the stations mostly recorded low values from grain maturity stage onward.

(*iv*) The mean YMI values showed the main peak at active tillering stage for most of the stations studied. The total YMI during the life span of rice crop varied widely from 477 mm at Bikramganj to 1523 mm at Pattambi.

(*v*) The AI values showed moderate aridity at early growth stages of the crop, which reduced during active tillering to flowering or grain formation stages and increased at advanced crop growth stages. No aridity was observed at some of the growth stages of the crop at different stations.

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