Int.J.Curr.Microbiol.App.Sci (2017) *6*(3): 809-817

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 3 (2017) pp. 809-817**
Journal homepage: http://www.ijcmas.com

IJCMAS INTERNATIONAL JOURNAL OF CURRENT MICROBIOLOGY AND APPLIED SCIENCES

Original Research Article https://doi.org/10.20546/ijcmas.2017.603.095

Quantification of Energy Indices Requirement of Cotton Varieties under Different Growing Environments

Premdeep*, Ram Niwas, M.L. Khichar, Abhilash and Abhijeet Sharma

Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar-125004, India
**Corresponding author*

Keywords

Energy indices, Sowing date, Varieties and indices use efficiency, PAR.

Article Info

Accepted:
15 February 2017
Available Online:
10 March 2017

A B S T R A C T

A field experiment was conducted at research area of Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the *kharif* season of 2013-14. The main plots treatments consisted of four date of sowing (2nd week of April, 4th week of April, 2nd week of May and 1st week of June) and the sub-plots consisted of three cotton varieties (HD 123, H 1098 and RASI 134). In the 2nd week of April sown crop consumed highest thermal and radiation indices, and efficiently converted the thermal/radiant energy into biomass production. The transmitted photosynthetic ally active radiation was lowest in G_1 followed by G_2, G_3 and G_4. All growth parameters and yield attributes were found highest in 2nd week of April sown crop. Among cotton varieties, RASI 134 consumed highest heat units, heliothermal units and photo thermal units as compared to H 1098 and HD 123 under different growing environments. The efficiency of PAR utilization for dry matter production was highest in RASI 134 during all phenophases. The efficiency of heat utilization was also more in RASI 134 as compared to H 1098 and HD 123 during all phenophases.

Introduction

Cotton is a one of the most important fiber crop in the world. It is also called as white gold. The primary product of the cotton plant has been the lint that covers the seeds within the boll. Important cotton producing states are Gujarat, Maharashtra, Tamil Nadu, Punjab and Haryana in India. Average area under cotton was 5.6 lakh hectares with an average production of 23 lakh bales and an average productivity of 691 kg/hectare in Haryana during 2013. Monga *et al.*, (2009) studied radiation pattern in tomato crop under different sowing environments. Singh (1999) observed decline in thermal use efficiency with delayed sowing and explained that it was due to less biomass production and less heat unit accumulation in delayed sown crops. A heat unit is a measure of the amount of heat energy a plant accumulates each day during the growing season and has been used to describe the development of crops (Peng *et al.*, 1989). A cotton plant can produce one open boll and four more bolls that are 85% mature with 1000 heat unit, and crop termination through defoliation at this stage of plant development results in a loss of about one per cent of total expected yield but does not reduce the fiber quality (Wrona *et al.*, 1996). Singh *et al.*, (2007) found that heat unit requirements of different genotypes of cotton increased with advancement of crop growth *i.e.* from germination to maturity. Kaur and Hundal (2006) also reported that the heat units accumulated were higher in early sown *Brassica* species as compared to middle and late sown crop. Brodick *et al.,* (2013) reported increase in light interception with increase in leaf area index and both were higher in ultra-narrow row crops. Hence this study was undertaken to quantify the energy indices requirement of cotton variety under different growing environments of Haryana.

Materials and Methods

A field experiment was conducted at the Research Farm of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar. It is situated in the semi arid zone at an elevation of 215m with a longitude of 75°46'E and latitude of 29°10' N. The main plots treatments consisted of four dates of sowing G_1, G_2, G_3 and G_4 and the sub-plots consisted of three varieties (HD 123, H 1098 and RASI 134). The forty eight treatment combinations were tested in split plot design to quantify the energy indices of cotton cultivars under different growing environments.

Agrometeorological observations

Quantum sensor was used to measure PAR after 30 days of sowing at 30 days interval during noon hours at top, middle and bottom of canopy. Pyr was used to measure global solar radiation at similar intervals. The reflected radiation was obtained by keeping the sensor inverted at 1m above the crop canopy and the sensor was also kept on ground across the rows diagonally and randomly sites to get transmitted radiation at the ground.

Energy/ heat indices

Energy indices *viz.*, heat unit, heliothermal unit, photothermal unit and thermal interception rate were computed using daily weather data. Cumulative heat units (HU) were determined by summing the daily mean temperature above base temperature and are expressed in °C day. This was calculated using the following formula.

$HU = \square(T_{max.} + T_{min.})/2 - T_b$

Where, T_{max} = Daily maximum temperature (°C), T_{min} = Daily minimum temperature (°C) &T_b= Minimum threshold/base temperature (10°C, WMO, 1996)

Heliothermal unit (HTU) represents the product of heat unit and bright sunshine hours for a day and is expressed in °C day hour, sums of HTU for particular phenophases of interest were determined according to the equation

$HTU = \square(HU \times n)$,

Where, n= Actual sunshine hours

Day and night is one of the basic factors controlling the period of vegetative growth in a photosensitive crop. Photothermal units (PTU) are product of heat units and maximum possible sunshine hours and are expressed in θ°C day hours. PTU was calculated using the following formula.

$PTU = \Sigma (HU \times N)$, Where, N = Maximum possible sunshine hours or day length

Intercepted photosynthetically active radiation (IPAR)

Daily solar radiation was computed by the expression

$Rs = Ra (1-r) (a+b (n/N)$

Where, Rs is solar radiation received at the surface of the earth (cal/cm^2), Ra is solar radiation received outside the atmosphere (cal/cm^2) taken from Smithsonian tables corresponding to the latitude values of Hisar, r is reflection coefficient (0.25) for green vegetations, a and b are constants, a= 0.256; b = 0.56 for Hisar, (Bishnoi *et al*., 1995). The PAR values were converted into MJ/m^2, daily IPAR was calculated using the following expression.

PAR = Rs x 0.48 (Oleson *et al*., 2000) & IPAR= PAR (1-e^{-kf}) (Rosenthal and Gerik, 1991).

Where, k is extinction coefficient = ln (I/Io)/F (Monsi and Saeki, 1953), F is cumulative leaf area index of foliage layer, Io is radiation energy at the top of the canopy, and I is radiation energy at a level inside the crop canopy.

Thermal Interception Rate (TIR)

Thermal interception rate is the multiplication of heat units with solar radiation intercepted by a plant. This was computed by the formula:

TIR = Σ (Rs/n) HU,

Where, TIR = Thermal interception rate (°C day MJ/plant) & T_b = Base/ threshold temperature (10 °C).

The radiation use efficiency is a ratio of biological yield and the radiation intercepted. It can be expressed by the following formula:

Radiation use efficiency (RUE) = Dry matter / Intercepted PAR

Thermal use efficiency is a ratio of dry matter and heat unit consumed by the crop. It can be represented by the following formula:

Thermal use efficiency = Dry matter / HU accumulated

Results and Discussion

Optical characteristics

The optical characteristics (Transmitted, Reflected and Absorbed PAR) of cotton varieties in four growing environments are presented in table 1. The maximum reflection (7.5%) was observed in G_1, followed by G_2 (7.0%), G_3 (6.8%) and G_4 (5.5%). The variety HD 123 showed maximum transmission of 14.7%, followed by H 1098 (10.4%) and RASI 134 (6.5%). Higher absorption (88.4%) was found in RASI 134 as compared to H 1098 (83.6%) and HD 123 (79.9%).

The minimum level of transmission and maximum absorption of PAR was recorded in RASI 134 and first sowing date ($G_{1)}$, because of maximum LAI recorded in same treatments. Transmission (%) was found to be higher in G_1 sown crop as compared to other sowing dates G_2 and G_3, G_4. This might be due to the lower leaf area index in late sown crop in comparison with early sown crop.

Energy indices

The various agrometerological energy based indices (HU, HTU, PTU, TIR and IPAR) were computed for different phenophases of cotton crop and thermal indices are depicted in figure 1, 2 and 3.

Cumulated thermal time was highest in G_1 followed by G_2, G_3 and G_4 growing environment at all phenological stages (Figure 1). These values recorded at physiological maturity were 3669.8, 3647.0, 3550.8 and 3447.6 °C day for G_1, G_2, G_3 and $G_{4,}$ respectively. RASI 134 accumulated highest number of heat units (2630.6 °C day) followed by H 1098 (2550.6 °C day) and HD 123 (2508.6 °C day) (Figure 1). The cotton crop sown on G_1 accumulated higher thermal units as compared to G_2,G_3 and G_4 sown crop because early sown crop utilized took more days to mature as compared to late sown.

Cumulative HTU at physiological maturity was higher in first sown crop as compared to delayed sown (Figure 2). HTU values at physiological maturity were 25509.6, 24406.3, 24149.9 and 24464.4 °C day hour for G_1, G_2, G_3 and G_4 respectively. Among cotton varieties, RASI 134 accumulated higher amount of HTU with the value of 20470.8 °C day as compared to H1098 and HD 123.Accumulation of HTU in early sown crop was higher due to more growing days and longer days available in early sown as compared to later sown crops. RASI 134 consumed maximum HTU due to more growth duration as compared to other varieties. Photothermal units were higher in G_1 followed by G_2, G_3 and G_4 at all phenological stages (Figure 3). These values at physiological maturity were 50577.5, 49720.1, 49632.6 and 48641.2 °C day hours for G_1, G_2 G_3 and G_4 respectively. RASI 134 accumulated higher PTU with the value 50345.3 °C day hour as compared to H 1098 and HD 123.The decrease in PTU accumulation with delay in sowing was due to the fact that delayed sowing experienced shorter days in combination with lower temperature which caused early reproductive phase in late sown crops. In case of cultivars, RASI 134 consumed maximum heat unit as compared to H 1098 and HD 123 might be the fact that it took more time upto maturity. The accumulated IPAR (intercepted PAR) was highest in the G_1 sown crop, followed by $G_{2,}$ G_3 and G_4 sown crop at all phenological stages (Figure 4). These values at physiological maturity were 10452.2, 9844.4, 9656.7 and 9530.0 MJ m^{-2} for G_1, $G_{2,}$ G_3 and G_4, respectively. Cultivar RASI 134 intercepted maximum PAR with value of 10053.7MJ m^{-2} followed by H 1098 and HD 123.The decrease in IPAR values with delay in sowing was due to reduction in leaf area index with delayed sowing. Thermal interception rate at different phenophases of cotton cultivars under different growing environments was worked out and is depicted in figure 5. TIR at physiological maturity was higher in first sown crop as compared to late sown cotton crops, thermal interception rate values were highest in G1 followed by G2, G3 and G4 sown crop at all phenological stages, the corresponding values were 113.4, 112.7, 110.7 and 103.5 °C day MJ/plant for G_1, $G_{2,}$ G_3 and G_4 respectively. RASI 134 showed highest amount TIR with value of 110.0 °C day MJ/plant as compared to H1098 and HD123.Thermal interception rate of cotton crop sown on G_1 was higher as compared to $G_{2,}$ G_3 and G_4 sown crops due to highest leaf area index produced by first sown crop. Radiation indices (IPAR and thermal interception rate) were higher in first growing environment as compared to other growing environments. This might be due to higher leaf area index recorded in first growing environment than that of others. IPAR and TIR were highest in RASI 134 because of maximum LAI produced by this cultivar.

Efficiency of energy conversion into dry matter

Thermal use efficiency (TUE) for dry matter production at various phenophases under different growing environments was presented in table 2. Significantly highest TUE was found in G1 followed by G2, G3 and G4, at all phenophases. Among the varieties, RASI 134 showed significantly higher TUE at all the phenophases followed by H 1098 and HD 123. TUE value was highest at 50% boll opening stage in all the treatments; decrease in TUE with delay in sowing was due to fact that delayed sowing of cotton crop led to early reproductive phase.

Phenophases wise variations in radiation use efficiency for biomass production of cotton varieties of four growing environments has been presented in table 3. Cotton crop sown on 2nd week of April (G_1) was most efficient in PAR utilization as comparison to crop sown on 4th week of April (G_2), 2nd week of May (G_3) and 1st week of June (G_4). RASI 134 showed higher RUE followed by H 1098 and HD 123 at all stages.

Table.1 Optical characteristics of cotton varieties under different growing environments

Absorption (%)	Transmission (%)	Reflection (%)	Treatments
Time of Sowing			
83.0	11.5	5.5	**2nd week April**
81.1	11.7	6.8	**4th week April**
78.5	14.5	7.0	**2nd week May**
72.3	20.2	7.5	**1st week June**
Varieties			
79.9	14.7	5.4	**HD 123**
83.6	10.4	6.0	**H 1098**
88.4	6.5	5.1	**RASI 134**

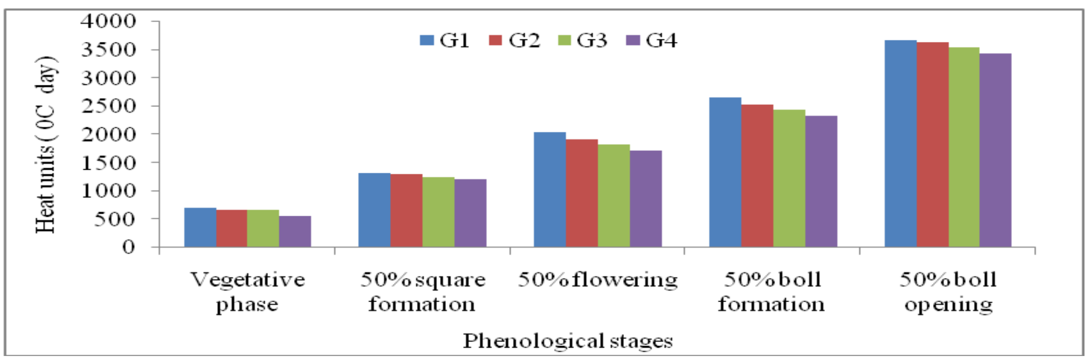
Table.2 Thermal use efficiency of cotton at different phenophases under growing environments and varieties

Thermal use efficiency (g/m²/°C day)					**Treatments**
50% boll opening	**50% boll Formation**	**50% flowering**	**50% square formation**	**Vegetative phase**	
0.56	0.55	0.35	0.12	0.07	**2nd week April**
0.50	0.49	0.32	0.10	0.06	**4th week April**
0.42	0.38	0.26	0.12	0.07	**2nd week May**
0.35	0.33	0.24	0.10	0.06	**1st week June**
0.06	0.03	0.02	0.01	0.01	**CD at 5%**
					Varieties
0.41	0.40	0.25	0.08	0.06	**HD 123**
0.47	0.43	0.29	0.10	0.07	**H 1098**
0.50	0.49	0.33	0.15	0.08	**RASI 134**
0.05	0.02	0.02	0.01	0.01	**CD at 5%**

Table.3 Radiation use efficiency of cotton at various phenophases under different growing environments and varieties

Radiation use efficiency (g/MJ)					Treatment
50% boll opening	**50% boll formation**	**50% flowering**	**50% square formation**	**Vegetative phase**	
1.15	1.06	0.76	0.34	0.26	**2nd week April**
1.05	1.03	0.70	0.27	0.18	**4th week April**
0.90	0.78	0.58	0.30	0.28	**2nd week May**
0.78	0.69	0.54	0.31	0.27	**1st week June**
0.15	0.06	0.05	NS	NS	**CD at 5%**
					Varieties
0.89	0.82	0.56	0.21	0.24	**HD 123**
0.99	0.89	0.64	0.29	0.20	**H 1098**
1.03	0.96	0.73	0.41	0.30	**RASI 134**
NS	0.05	0.04	0.11	0.04	**CD at 5%**

Fig.1 Heat units consumed by cotton at various phenophases under different growing environments and varieties



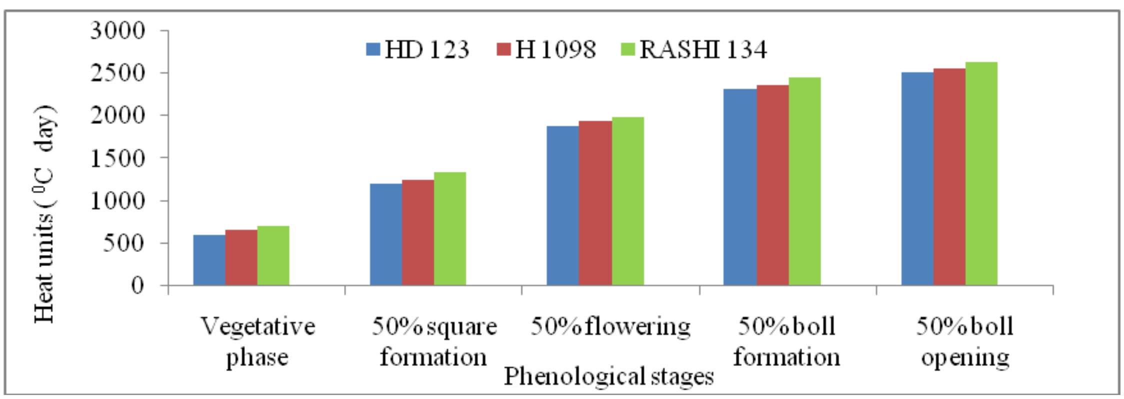


Fig.2 Heliothermal unit's requirement of cotton at various phenophases under different growing environments and varieties

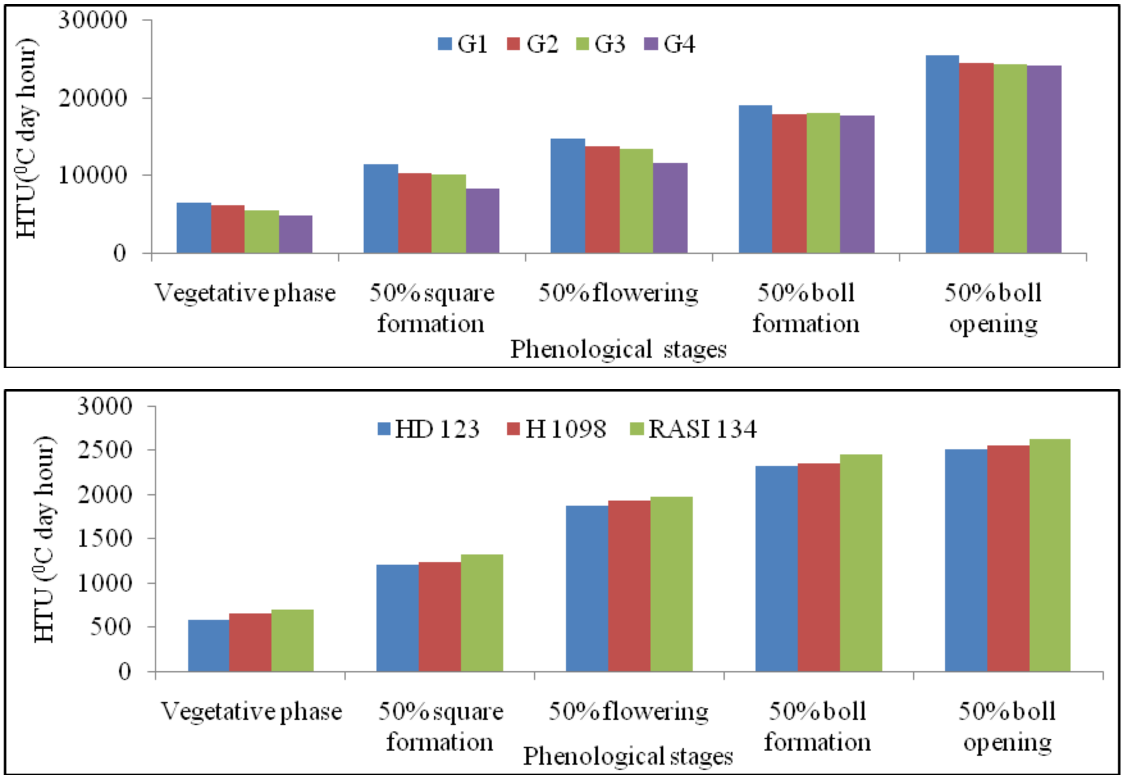


Fig.3 Photothermal unit requirement of cotton at various phenophases under different growing environments and varieties

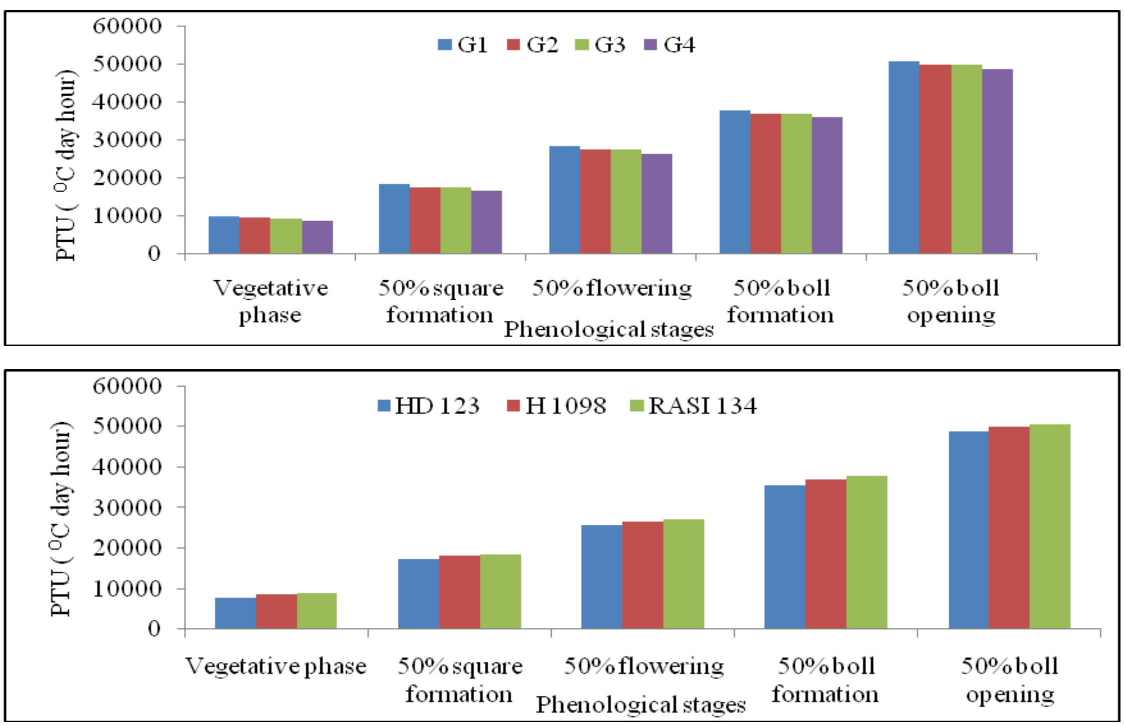
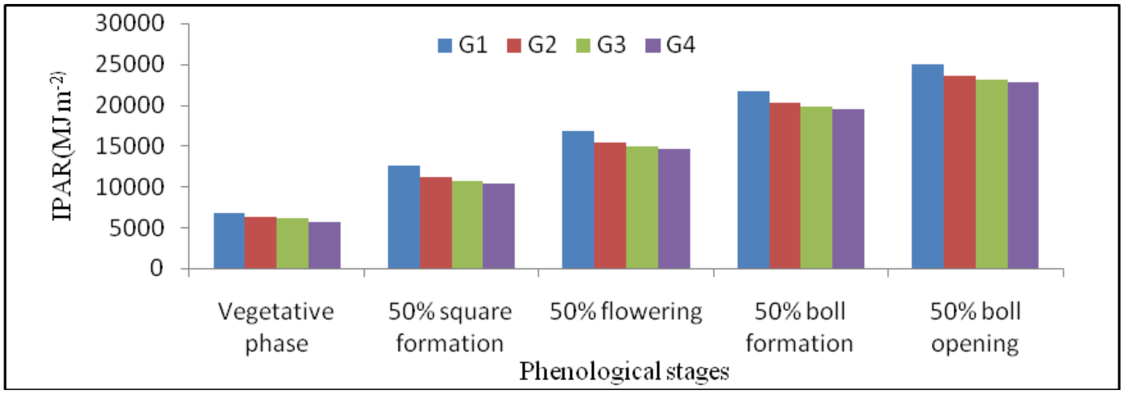


Fig.4 Photosynthetically active radiation intercepted by cotton at various phenophases under different growing environments and varieties



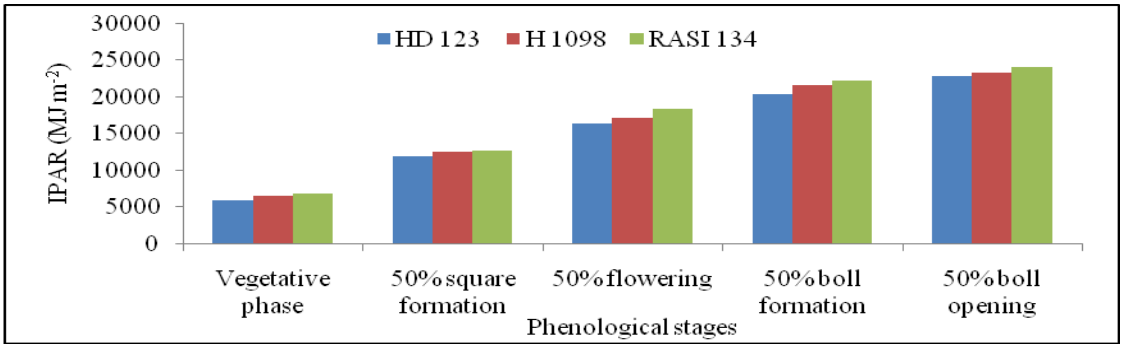
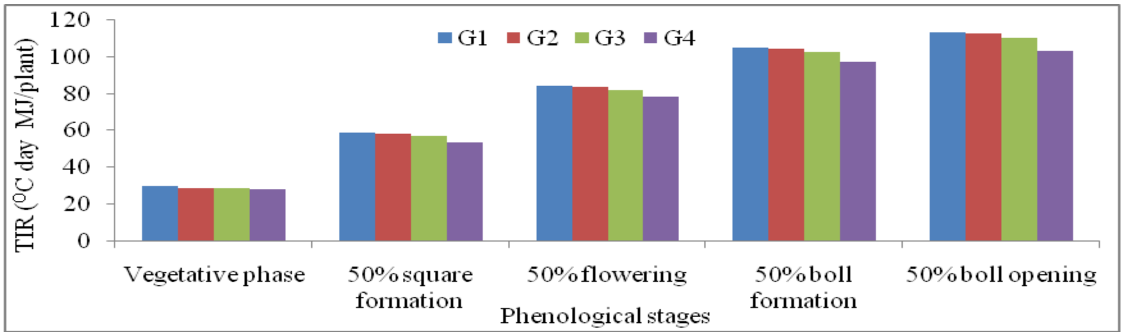
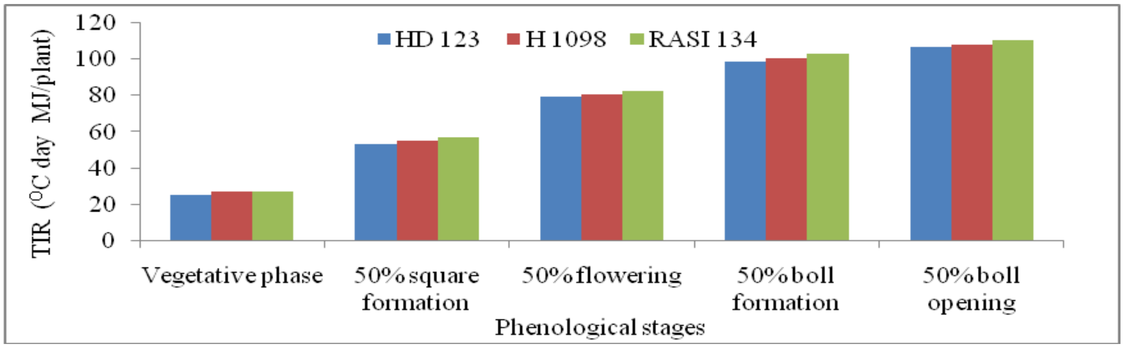


Fig.5 Thermal interception rate of cotton at various phenophases under different growing environments and varieties





Highest RUE in earlier sown crop and cultivar RASI134 was due to the maximum PAR absorption and dry matter production, both of which decreased subsequently due to reduction in LAI with delayed sowing. Though amount of PAR received above the canopy was almost same in all treatments, the proportion of intercepted PAR differed because of differential crop cover owing to variation in LAI and varying levels of biomass production in different treatments, implying that RUE also differed. RASI 134 showed higher RUE followed by H 1098 and HD 123 at all stages. The maximum value of RUE for dry matter production was observed at 50% boll opening stage in all treatments because of maximum LAI recorded at this phenophase, maximum RUE in the earlier sown crop was due to the maximum PAR absorption and dry matter production, both of which decreased subsequently due to reduction in LAI with the delayed sowing.

In conclusion, energy indices requirement and thermal interception rate were higher in 2^{nd} week of April sown crop as compared to 4^{th} week of April, 2^{nd} week of May and 1^{st} week of June at all phenological stages. PAR interception was highest in crop sown during 2^{nd} week of April followed by 4^{th} week of April, 2^{nd} week of May and 1^{st} week of June. RASI134 consumed highest HU, HTU and PTU as compared to H1098 and HD 123.The efficiency of energy utilization for dry matter production was highest in RASI 134 and in 2^{nd} week of April sown crop.

References

Brodrick, R., Bange, M.P., Milroy, S.P. and Hammer, G.L. 2013. Physiological determinants of high yielding ultra-narrow row cotton: Canopy development and radiation use efficiency. *Field Crops Res.*, 148: 86–94.

Kaur and Hundal. 2006. Prediction of growth and yield of *Brassica species* using thermal indices. *J. Agrometeorol.*, 8(2): 179-185.

Monga, R.K., Singh, R., Prakash, V. and Narang, R.S. 2009. Assessment of spectral response of tomato (*Lycopersicum esculentum* L.) to varying microclimate in Western Ghats conditions. *Indian J. Agron.*, 35(1&2): 153-158.

Peng, S., Krieg, D.R. and Hicks, S.K. 1989. Cotton Lint yield response to accumulated heat units and soil water supply. *Field Crops Res.*, 19: 253-262.

Singh, R. 1999. Crop weather studies in mustard under different environments. Ph.D. Thesis., CCS HAU, Hisar.

Singh, S., Butter, G.S. and Singh, S. 2007. Heat use efficiency of Bt cotton cultivars in the semi- arid region of Punjab. *J. Agrometeorol.*, 9(1): 122-124.

Wrona. A.F., J.C. Banks, K. Hake, K., Lege, M. Patterson, B. Roberts. C.E. Snipes, and J. Supak. 1996. Achieving a clean finish. *Cotton Phyiol. Today*, 7(6): 25-31.

How to cite this article:

Premdeep, Ram Niwas, M.L. Khichar, Abhilash and Abhijeet Sharma. 2017. Quantification of Energy Indices Requirement of Cotton Varieties under Different Growing Environments. *Int.J.Curr.Microbiol.App.Sci.* 6(3): 809-817. doi: https://doi.org/10.20546/ijcmas.2017.603.095