J. Cotton Res. Dev. **29** (2) 268-272 (July, 2015)

Agrometeorological indices and intercepted photosynthetically active radiation in cotton crop under different growing environments

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ABSTRACT: The field experiment was conducted for agrometeorological indices of cotton crop under different growing environments with 3 cotton cultivars *i.e.* HS 6, RASI 134 and MRC 6304 and 2 dates of sowing *viz.,* 30th April and 30th May at Research Farm, Department of Genetics and Plant Breeding CCSHAU Hisar at longitude of 75^0 46 ′ E and latitude of $29^0$10 ′ N during *kharif* 2011. The crop was grown under protected and unprotected conditions. Daily meteorological data was recorded at Agrometeorological Observatory which was used for computation of following agrometerological indices *i.e.* heat unit, heliothermal and photothermal unit. Intercepted photosynthetically active radiation was measured at different phenological stages. Cotton cultivar RASI 134 took significantly higher number of days at all phenological stages as compared to other cultivars *viz.,* HS6 and MRC 6304. The values of thermal indices accumulated were higher under protected conditions in all the treatment combination than unprotected conditions. The heat unit, photothermal units and heliothermal units consumption was maximum in cotton sown in 30th and was minimum in 30th May sown crop. The more PAR value (26845 cal cm^{-2}) was recorded in RASI 134 as compared to MRC 6304 (25387 cal cm^{-2}) and HS 6 (24185 cal cm^{-2}) under protected conditions. In case of unprotected conditions the highest PAR value was observed for cultivar RASI 134 (26611 cal cm^{-2}) followed by MRC 6304 (24296 cal cm^{-2}) and HS 6 (22515 cal cm^{-2}).

Key words: Agrometeorological indices, growing environments, intercepted photosynthetically active radiation

Cotton occupies a unique position in textile world with millions of people engaged in its cultivation, processing and marketing etc therefore, cotton is rightly called as the lifeline of economy all over Asia. The meteorological factors play a vital role in the growth and development and population build up of insect species of cotton crop. Temperature is most important weather parameter that affects the crop growth, phenology and development of any crop. Plants have a definite temperature requirement before they attain certain phenological stages. Temperature regulates many of the physical and chemical processes within the plant, which in turn control the rate of growth and development toward maturity. Influence of temperature on phenology and yield of crop plants can be studied under field conditions through accumulated heat unit system (Kumar *et al.*, 2012). Agroclimatic indices *i.e.* thermal time, photothermal and heliothermal units are useful for assessing the agroclimatic resources in crop planning and reflecting the impact of agrometeorological variables at different crop growth stages (Khichar and Ram Niwas, 2006). The present study has been done to determine the crop phenology and different agrometeorological indices under varied sowing environment of cotton crop.

A field experiment was conducted during *kharif* 2011-2012 at Research Farm, Department of Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar which situated in the semi arid zone at an elevation of 215.2 m with a longitude of 75^0 46 ′ E and latitude of $29^0$10 ′ N. The experiment was conducted in factorial RBD with 2 date of sowing *viz.,* 30 April and 30 May 2011 and 3 cultivars HS 6, RASI 134 and MRC 6304 with 4 replications. The cotton crop was grown under protected and unprotected conditions. Delinted and certified seeds of recommended HS 6, RASI 134 and MRC 6304 of cotton cultivars were sown in 2 growing environments by hand plough, keeping a distance of 67.5 cm from row to row. Thinning was done one month after sowing maintaining a plant to plant distance of 30 cm. The dates of occurrence of different phenological events *viz.,* 50 per cent square formation, 50 per cent flowering , 50 per cent boll formation and 50 percent boll opening were recorded when 75 per cent of the plants in each replication reached the respective stage. Daily meteorological data recorded at Agrometeorological Observatory was used for computation of following agrometerological indices.

Heat unit: Cumulative heat units (HU) were determined by summing the daily mean temperature above base temperature and are expressed in ^{0}C day. This was calculated using the following formula:

$$Heat\ Unit\ (^{\circ}C\ day) = \sum_{a}^{b} \frac{Tmax + Tmin}{2} - Tb$$

Whereas,

a = Date of start of a phenophase

b = Date of end of the phenophase

$T_{max.}$ = Daily maximum temperature (^{o}C)

$T_{min.}$ = Daily minimum temperature (^{o}C)

T_b = Minimum threshold / base temperature (12^{o}C, WMO, 1996)

Heliothermal unit: Heliothermal units (HTU) for a day represent the product of heat unit and bright sunshine hours for that day and are expressed in ^{o}C day hr. The sums of HTU for particular phenophases of interest were determined according to the equation:

HTU (^{0}C day hr) = © (HU x BSS)

Where,

BSS = Bright sunshine hr

Photothermal unit: Day and night is one of the basic factors controlling the period of vegetative growth in a photosensitive crop. Photothermal units (PTU) are cumulative value of heat units multiplied by maximum possible sunshine hours and are expressed in ^{0}C day hours. PTU was calculated using the following formula:

PTU (^{0}C day hrs) = Ó (HU x N)

Where;

N = Maximum possible sunshine hr or day length

Intercepted photosynthetically active radiation: Quantum/photometer (Li 185B) was used to measure the photosynthetically active radiation (PAR) in the range of 400-700nm at top and bottom of the crop canopy. The reflected radiation was obtained by keeping the sensor inverted at 1m above the canopy and the sensor was also kept on ground across the rows diagonally at random places to get transmitted radiation at the ground. The radiation observations were taken on diurnal basis at different phenological stages during 0800-1600 hr. The fraction of PAR intercepted by the crop was calculated as intercepted photosynthetically active radiation, IPAR= (1-r) PAR_i. The fraction of absorbed photosynthetically active radiation was computed as (APAR) = (1-r-t) PAR_i where, r is reflected PAR, t is transmitted PAR and PAR_i is incident PAR.

Crop phenology: The numbers of days taken for different phenophases of cotton cultivar during the experiment are presented in Table 1. The cotton crop took maximum number of days for 50 per cent boll opening stage compared to the completion of other stages in both dates of sowing. The number of days required to attain different phenological stages of all cultivars decreased with delay in sowing. (May 30). The crop duration reduced with delay in sowing on account of shorter vegetative and reproductive phenophases. RASI 134 took significantly higher number of days at all phenological stages as compared to HS6 and MRC 6304 (Table 1) in both date of sowing. With delay in sowing (May 30) took lesser number of days as compared to early sowing for 50 per cent square formation, 50 per cent flowering, 50 per cent boll formation and 50 per cent boll opening stages. The number of days taken from sowing to 50 per cent boll opening was highest in early sown crop and decreased consistently with subsequent sowing. Protected cotton crop took more days for different phenological stages as compared to unprotected cotton crop due to high foliage.

Agrometeorological indices: The agrometeorological indices are computed for different phenophases of cotton crop under both protected and unprotected conditions and are presented in Table 2.

Heat units: In case of protected conditions the heat units (HU) consumed by cotton crop to mature was maximum in cotton sown on 30th April (3698°C days) and followed by 30th May (3459°C days). The corresponding values for unprotected conditions were 3558 and 3294°C days in 30th April and 30th May, respectively. Higher HU was consumed by RASI 134 (3766 °C days) as compared to MRC 6304 (3605°C days) and HS 6 (3437°C days) under protected conditions. RASI 134 (3631°C days) consumed more heat units as compared to MRC 6304 (3459°C days) and HS 6 (3191°C days) for whole life cycle under unprotected conditions. The cotton crop required higher heat units for maturity under protected conditions as compared to unprotected conditions in all the treatments. 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.

The values of thermal indices accumulated were also higher under protected conditions in all the treatment combination than that of unprotected conditions. This might be due to biotic stress by leaf curl disease which caused faster development and matured earlier in unprotected conditions as compared to protected conditions of cotton crop. In case of RASI 134 consumed maximum heat unit as compared to MRC 6304 and HS 6. This might be due the fact that to more time was taken upto maturity. Gudadhel *et al.,* (2013) evaluated the Agrometeorological Indices in relation to crop phenology of cotton GDD, HTU and PTU for cotton crop were 2478.8, 21171.5and 20209.6 °C day, respectively.

Heliothermal units: Heliothermal units (HTU) requirement under protected condition was higher in 30th April sown crop (25290°C day hr) as compared to 30th May sown crop (23455°C day

Table 1. Number of days required for different phenophases of cotton cultivars RASI 134, HS 6 and MRC 6304 in different growing environments under protected and unprotected conditions

Treatments	Phenological stages							
	Square formation (50%)		Flowering (50%)		Boll formation (50%)		Boll opening (50%)	
	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
HS 6								
30th April	43	38	68	61	96	87	135	130
30th May	36	33	61	52	85	75	126	114
P=0.05	1.1	0.6	1.8	0.9	1.6	1.2	1.5	1.8
MRC 6304								
30th April	46	42	72	63	101	91	142	136
30th May	40	37	65	58	88	79	135	128
P=0.05	0.7	0.4	0.6	1.5	2.6	3.5	1.1	1.4
RASI 134								
30th April	50	45	78	70	103	96	150	141
30th May	44	39	70	61	91	84	139	136
P=0.05	0.6	0.5	0.6	0.4	1.6	1.2	1.5	0.5

hr) under unprotected conditions. Similar trend of growing environment was observed under unprotected conditions and recorded 24219 and 22721°C day hr for 30th April and 30th May sown crop, respectively. The higher HTU (25914°C day hours) were consumed by RASI 134 as compared to MRC 6304 (24479°C day hr) and HS 6 (23438°C day hr) under protected conditions. Heliothermal units under protected conditions were reported to be higher as compared to unprotected conditions. Late sowing forced the plants to complete their life cycle with a short period of time resulting in decreased HTU.

Photothermal units : Under protected conditions the Photothermal units (PTU) consumption was maximum in cotton sown in 30th April (49186°C day hr) and was minimum in 30th May (46236°C day hr) sown crop. Similar trend was observed under unprotected conditions and consumed 47476 and 44195°C day hr for crop sown on 30th April and 30th May, respectively. The cultivar RASI 134 consumed more PTU (50008°C day hr) as compared to MRC 6304 (48023°C day hr) and HS 6 (45990°C day hr) under protected conditions. Under unprotected conditions also the maximum PTU was consumed by RASI 134 (48368°C day hr) followed by MRC 6304 (46236°C day hr) and HS 6 (42934°C day hr). The protected cultivars showed more consumption of PTU for all phenophases as compared to unprotected conditions in both environments. Singh *et al.,* (2007) found that heat unit requirements of different genotypes of cotton

Table 2. Variation in Agrometeorological indices at different phenophases of cotton cultivars under protected and unprotected conditions under different growing environments

Treatments	Square formation (50%)		Flowering (50%)		Boll formation (50%)		Boll opening (50%)	
	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
HU (°C days)				**Date of sowing**				
30th April	1258.0	1138.3	1972.9	1768.9	2682.5	2445.7	3698.5	3558.4
30th May	1081.6	908.05	1742.7	1541.6	2343.0	2103.7	3459.4	3294.4
				Cultivars				
HS 6	1081.6	961.7	1768.9	1567.8	2445.7	2181.9	3437.6	3191.7
MRC 6304	1142.9	1055.4	1846.9	1636.8	2526.4	2265.4	3605.1	3459.4
RASI 134	1286.1	1138.3	2001.1	1795.8	2603.6	2420.55	3766.3	3631.4
HTU (°C days hr)				**Date of sowing**				
30th April	11189.3	10247.2	14562.8	13262.1	18863.7	17366.9	25290.5	24219.2
30th May	9859.3	8106.1	12986.5	12593.6	16624.3	15366.0	23455.7	22721.3
				Cultivars				
HS 6	9859.3	8669.9	13262.1	12869.3	17366.9	16031.5	23438.1	21918.2
MRC 6304	10212.6	9583.7	13640.1	12676.4	17757.7	16378.1	24479.7	23455.7
RASI 134	11276.5	10247.2	14833.5	13476.9	18335.0	17120.0	25914.1	24755.4
PTU (°C days hr)				**Date of sowing**				
30th April	16955.2	15290.5	26840.8	24042.1	36343.0	33196.0	49186.2	47476.0
30th May	14503.0	12150.8	23696.4	20922.3	31828.0	28613.6	46236.5	44195.7
				Cultivars				
HS 6	14503.0	12868.5	24042.1	21268.0	33196.0	29659.6	45990.7	42934.6
MRC 6304	15374.3	14157.3	25144.4	22247.7	34274.8	30788.9	48023.2	46236.5
RASI 134	17346.0	15290.5	27221.5	24415.1	35297.5	32859.6	50008.1	48368.9
IPAR (Cal cm^{-2})				**Date of sowing**				
30th April	9828.2	9017.6	14086.2	12622.3	18896.4	17265.3	26200.6	25052.5
30th May	8640.8	7232.4	12398.2	11449.0	16501.4	15005.4	24296.7	23301.1
				Cultivars				
HS 6	8640.8	7700.8	12622.3	11673.0	17265.3	15627.2	24185.5	22515.0
MRC 6304	8995.6	8416.7	13121.9	11861.8	17762.3	16091.5	25387.0	24296.7
RASI 134	9963.0	9017.6	14319.7	12828.7	18333.7	17030.7	26845.4	25611.1

increased with advancement of crop growth *i.e.* from germination to maturity.

Intercepted photosynthetically active radiation: Under protected conditions intercepted photosynthetically active radiation (PAR) were higher in cotton sown on 30th April (26200 cal cm^{-2}) as compared to 30th May (24296 cal cm^{-2}) sown crop under protected conditions, respectively. Similar trend of growing environment was observed under unprotected conditions and recorded 25052 and 23301 cal cm^{-2} for 30th April and 30th May sown crop, respectively. The more PAR value (26845 cal cm^{-2}) was recorded in RASI 134 as compared to MRC 6304 (25387 cal cm^{-2}) and HS 6 (24185 cal cm^{-2}) under protected conditions. In case of unprotected conditions the highest PAR value was observed for cultivar RASI 134 (26611 cal cm^{-2}) followed by MRC 6304 (24296 cal cm^{-2}) and HS 6 (22515 cal cm^{-2}). Intercepted photosynthetically active radiation by cotton cultivars was more in case of protected conditions as compared to unprotected conditions. Similar results on radiation were found by Sindhu *et al.,* (2009) in brinjal crop. The higher productivity of cotton crop was observed in California can be attributed to larger amounts of incident and intercepted radiation (Evangelos *et al.*, 2012).

This study indicated that change in microclimate due to different sowing time is reflected during individual phonological stage. The differences in agrometeorological indices for different phonological stages indicated that accumulated temperature can be utilized for dry biomass and crop yield forecast.

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Recieved for publication : October 25, 2013
Accepted for publication : September 19, 2014