CONTEMPORARY RESEARCH IN INDIA
ISSN 2231 - 2137

GROWING DEGREE DAY'S REQUIREMENT FOR *BT* COTTON UNDER DIFFERENT PHENOPHASES

P. S. Kamble, S. B. Kharbade, A. A. Shaikh, V. A. Sthool and J. D. Jadhav

Department of Agricultural Meteorology, College of Agriculture, Pune

Received: 14/05/2018	Edited: 26/05/2018	Accepted: 04/06/2018

Abstract: *An experiment was conducted during Kharif 2015-16 at Department of Agricultural Meteorology Farm, Centre of Advanced Faculty Training (CAFT) in Agricultural Meteorology, College of Agriculture, Pune, (Maharashtra). An experiment was conducted in split plot design with three replications. The gross and net plot sizes were 7.2 mX 5.4 m and 5.4 m x 3.6 m, respectively, with 90 cm x 90 cm spacing, three replications with sixteen treatment combinations were formed due to cotton hybrids and sowing windows. The main plot treatments comprises of four Bt cotton hybrids viz., Vitthal (V_1) , Bhakti (V_2), Ankur-3028 (V_3) and US-4746 (V_4) and sub plot treatments were four sowing windows viz., 24th MW (11th -17th June), 25 th MW (18th -24th June), 26th MW (25th June -1st July), 27thMW (2nd July - 8 th July). The growing degree days were significantly affected by different phenophases.Higher GDD recorded in Vitthal hybrid followed by Bhakti, Ankur-3028 and US-4746 during the experimental period From P_1-sowing to emergence, P_2- emergence to seedling stage, P_3- seedling stage to square formation, P_4- square formation to flowering, P_5-flowering to boll setting,P_6- boll setting to boll bursting, P_7-boll bursting to first picking ,P_8-1st picking to 2nd picking, P_9-2nd picking to 3rd picking to P_{10}-3rd picking to 4th picking. The lowest GDD was required to complete P_1 phenophase (Sowing to emergence) due to the less days required to complete this phenophase. The highest GDD was required to complete P_6 phenophase (P_6-boll setting to boll bursting) due to the maximum number days required to complete this phenophase.The duration of 50 per cent boll opening was more in normal sowing windows D_1 (145 days) as compared to late sowing D_4 (135 days) indicated more duration of boll development in normal sowing than late sowing. The growing degree days (GDD) occurred as affected by sowing windows were 1848 ^{0}C-d in normal sowing windows than829^0 cd late sowing windows.*

Key words: *GDD, Cotton, Phenophases.*

Cotton, popularly known as white gold, or the 'king of the fiber', provides livelihood to 60 million peoples of India by way of support in agriculture, processing and textiles. It accounts for 75 % of the fiber used in textile industry and contributes 5 % of the GDP. Cotton is the world's most important fiber crop and the second most oilseed crop. Cotton lint is still a principle economic raw material from the cotton plant, provides a high quality fiber for the world's textile industry. The cotton seeds, the primary byproduct of lint production is an important source of oil and a high protein meal used as livestock feed. The waste after ginning is used as fertilizer and the cellulose from the stalk can be used for products such as paper and cardboards.

Heat units or growing degree days (GDD) are widely used in agriculture to predict the approximate date of phenological stages and maturity of the crop. Heat units can also be used for early assessment of the final yield of the crop. Yield of seed cotton is dependent on many factors of which the rate of flowering, length of flowering period, the percentage of setting and the size of the bolls are important. Earliness of crop maturity in cotton may be defined as the extent to which squares initiation, flower occurrence, complete boll opening and maturity takes place in relation to the time of planting. GDD, also called heat units or thermal time, is a simple index for relating plant growth, development and maturity to air temperature.

GDD also called heat units or thermal time is a simple index for relating plant growth, development and maturity to air temperature. Degree-day units (°C-d) are often used in agriculture in order to estimate or predict the lengths of different phases of the development in crop plants. Degree day models are common method to monitor crop progress and predict phenology of cotton. GDD are based on the concept that real time to attain phenological stage is linearly related to temperature in the range between base temperature and optimum temperature. The duration of each phenophase determines the accumulation and partitioning of dry matter in different parts as well as crop responses to environmental and external factors. The air temperature based indice like growing degree days (GDD) can be successfully used for describing phenological behavior and other growth parameters like leaf area development, biomass production and seed yield etc.

Material and Methods

The field experiment was conducted at the Department of Agricultural Meteorology Farm, College of Agriculture, Pune during *Kharif* 2015-16.

The topography of the experimental field was of Pather series. It was uniform and leveled. The soil was well drained having depth up to 90 cm. In order to study the physical and chemical properties of soil, the soil samples from 0-30 cm depth at 10 different randomly selected locations were collected from the experimental area before laying out the experiment. The soil of experimental site was sandy clay loam in texture.

Pune is situated in the sub tropical region (Plain Zone) on the latitude 18^0 22' N and longitude $73^0$51' E and having an altitude of 557.7 m above the mean sea level. The average annual rainfall of Pune is 675 mm which is distributed from second fortnight of June to second fortnight of October. Out of total rainfall, about 75 per cent is received from June to September from South-West monsoon, while remaining is received from north-east monsoon during October and November.

The maximum temperature during the month of April and May ranged between 34ºC and 40ºC. but on the onset of monsoon, it drops down to 27ºC. In the month of July and August, it ranged between 26 and 30ºC.

The minimum temperature varied from 6 to 10ºC in winter season from November to middle of February. Humidity during monsoon period i.e. from June to September is quite high in morning (about 85 to 93 per cent). The evening humidity generally ranged between 43 to 83 per cent. During summer season, morning and evening humidity decreased and it ranged between 49 to 51 per cent, respectively. In Pune, thus mostly dry and medium hot weather prevailed during the summer season.

The details of the treatments along with symbols are presented in Table 1.

a. Season : *kharif*, 2015-16
b. Experimental design : Split plot design
c. Number of replications : Three
d. Treatments : 1. Main plot : Cotton hybrids
2. Sub plot : Sowing windows
e. Spacing : 90 cm x 90 cm
f. Plot size :
i Gross : 7.2 m x 5.4 m^2
ii Net : 5.4 x 3.6 m^2
g. Place of research work : Department of Agricultural Meteorology Farm, College of Agriculture, Pune.

Table 1: Treatments details with symbols

Sr. No.	Treatment details	Symbol used
A.	**Main plot treatments: Cotton hybrids**	
1	Vitthal	V_1
2	Bhakti	V_2
3	Ankur-3028	V_3
4	US-4746	V_4
B.	**Sub plot treatments: Sowing windows**	
1	24 MW (11^{th} -17^{th} June)	D_1
2	25 MW (18^{th} -24^{th} June)	D_2
3	26 MW (25^{th} June-1^{st} July)	D_3
4	27 MW (2^{nd} -7^{th} July)	D_4

Growing Degree Days (GDD)

Temperature is a major environmental factor that determines rate of plant development (Johnson and Thornley, 1985). The temperature required and range of optimum temperature varies with sowing windows and available soil moisture. Thermal response of sowing windows can be quantified by using the heat unit or thermal time concept. Thermal time or growing degree days is calculated according to the equation,

$$G.D.D. = \sum_{i=1}^{n} [(T_{max.} + T_{min.})/2 - Tb]$$

Where,

G.D.D. = Growing degree days

$T_{max.}$ = Daily maximum temperature of day i (^{0}C)

$T_{min.}$ = Daily minimum temperature of day i (^{0}C)

Tb = Base temperature

In present study, the base temperature of cotton was taken as 15.5^{0}C.

Phenophases selected for the experiment:

From P_1-sowing to emergence, P_2- emergence to seedling stage, P_3- seedling stage to square formation, P_4-square formation to flowering, P_5-flowering to boll setting,P_6-boll setting to boll bursting, P_7-boll bursting to first picking ,P_8-1^{st} picking to 2^{nd} picking, P_9-2^{nd} picking to 3^{rd} picking to P_{10}-3^{rd} picking to 4^{th} picking.

Results and Discussion

Estimation of growing degree days (GDD)

The data on the cumulative growing degree days of cotton as influenced by different cotton hybrids and sowing windows are presented in Table 2 . Total GDD required for completion of growth of cotton crop was determined in degree days. The data given in the Table 2.showed that the number of growing degree days was accumulated during the each phenophases at the base temperature of 15.5^{0}C (60 ^{0}F). The results showed that the growing degree days were significantly affected by different phenophases. From P_1-sowing to emergence, P_2-emergence to seedling stage, P_3- seedling stage to square formation, P_4-square formation to flowering, P_5-flowering to boll setting,P_6-boll setting to boll bursting, P_7-boll bursting to first picking ,P_8-1^{st} picking to 2^{nd} picking, P_9-2^{nd} picking to 3^{rd} picking to P_{10}-3^{rd} picking to 4^{th} picking. The lowest GDD was required to complete P_1 phenophase (sowing to emergence) due to the less days are required to complete this phenophase. The highest GDD was required to complete P_6 phenophase (P_6-boll setting to boll bursting) due to the maximum number days are required to complete this phenophase. Similar results were closely matched with Hutmacher*et al.* (2002) observed degree day heat units required for cotton at different phenophases from emergence to 60 % boll opening at the base temperature of 60 ^{0}F (15.5 ^{0}C). He reported that heat unit accumulated during emergence to I square, emergence to I bloom, emergence to peak bloom, emergence to I open boll and emergence to 60% open boll were 425-500, 750-900, 1350-1500, 1650-1850 and 2200-2350, respectively. Whereas, late sowing resulted in significant reduction in days to 50 % flowering, days to 50 % boll bursting and days to maturity as well as number of GDDs for boll bursting and maturity

compared to normal sowing. These experimental findings supported with Ban *et al.* (2015).

Effect of cotton hybrids:

The Vitthal hybrid registered higher amount of GDD in various phenophase from sowing to harvest as compared to rest of the cotton hybrids due to higher number of days to attain different phenophases and growing degree days were required. Whereas, US-4746 registered lower amount of GDD than rest of the hybrids due to lower number of days required to attain different phenophases and growing degree days were required to complete its life cycle during both the year of experimentation period. Higher GDD recorded in Vitthal hybrid followed by Bhakti, Ankur-3028 and US-4746 during both the experimental period (2015-16 and 2016-17). These results are in the line of Singh *et al.* (2007), Young *etal.*(1980),Hebbar*etal.*(2002) and Prakash*etal.*(2010) who reported that the early sown crop experienced the maximum cumulative growing degree days, whereas, the late sown crop experienced the minimum cumulative growing degree days.

Table 2: Phenophase wise cumulative growing degree days (GDD) of cotton as influenced by different treatments (2015-16)

Treatment	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
V_1D_1	38	28	207	175	360	443	216	254	55	72
Cumulative	38	66	273	448	808	1251	1467	1721	1776	1848
V_2D_1	57	51	190	173	558	260	189	14	57	51
Cumulative	57	108	298	471	1029	1289	1478	1492	1549	1600
V_3D_1	67	52	174	130	440	253	174	52	67	52
Cumulative	67	119	293	423	863	1116	1290	1342	1409	1461
V_4D_1	36	12	146	111	303	364	167	35	36	12
Cumulative	36	48	194	305	608	972	1139	1174	1210	1222
$V1D_2$	33	15	180	173	299	363	184	199	56	73
Cumulative	33	48	228	401	700	1063	1247	1446	1502	1575
V_2D_2	23	11	138	170	294	329	165	184	54	61
Cumulative	23	34	172	342	636	965	1130	1314	1368	1429
V_3D_2	39	18	159	173	292	349	180	50	39	18
Cumulative	39	57	216	389	681	1030	1210	1260	1299	1317
V_4D_2	50	35	128	91	386	217	137	51	50	35
Cumulative	50	85	213	304	690	907	1044	1095	1145	1180
V_1D_3	65	50	164	126	399	260	181	51	65	50
Cumulative	65	115	279	405	804	1064	1245	1296	1361	1411
V_2D_3	25	21	147	173	206	285	185	174	51	60
Cumulative	25	46	193	366	572	857	1042	1216	1267	1327
V_3D_3	33	23	146	162	261	246	165	152	52	78
Cumulative	33	56	202	364	625	871	1036	1188	1240	1318
V_4D_3	33	20	129	96	236	245	117	117	63	82
Cumulative	33	53	182	278	514	759	876	993	1056	1138
$V1D_4$	34	30	130	135	295	298	144	141	76	95
Cumulative	34	64	194	329	624	922	1066	1207	1283	1378
V_2D_4	46	53	129	97	391	249	135	50	46	53
Cumulative	46	99	228	325	716	965	1100	1150	1196	1249
V_3D_4	30	18	76	90	200	218	89	136	68	46
Cumulative	30	48	124	214	414	632	721	857	925	971
V_4D_4	18	14	65	53	159	169	89	102	70	90
Cumulative	18	32	97	150	309	478	567	669	739	829

Effect of sowing windows

The GDD was estimated at different phenophases from P_1-sowing to emergence, P_2-

emergence to seedling stage, P_3- seedling stage to square formation, P_4-square formation to flowering, P_5-flowering to boll setting,P_6-boll setting to boll bursting, P_7-boll bursting to first picking, P_8-1st picking to 2nd picking, P_9-2nd picking to 3rd picking and P_{10}-3rd picking to 4th picking. The duration of 50 per cent boll opening was more in normal sowing windows D_1 (145 days) as compared to late sowing D_4 (135 days). Duration of 50 per cent boll development was also more in normal sowing D_1 (119 days) as compared to late sowing windows D_4 (110 days) indicated more duration of boll development in normal sowing than late sowing. The growing degree days (GDD) occurred as affected by environments were 1848 ^{0}C-d and 2128^{0}C-d in normal sowing windows 829^0 cd and 1018^0 C d in late sowing windows. The number of days and growing degree days accumulated were significantly decreased with each delay sowing windows during the period of experimentation. The number of days required to attain different phenophases and growing degree were higher in D_1(11-17 June) sown crop as compared to rest of sowing windows followed D_2, D_3 and D_4 during the experimental period(2015-16).These results supported with findings of Landivar*et al.* (1996) They found that the heat unit requirement from planting to emergence 50-60 days ^{0}C, emergence to first square it was 425-475 days ^{0}C, square to first flower it was 300-350 days ^{0}C, planting to first flower to open ball it was 850-950 days ^{0}C and planting to harvest ready it was 2200-2600 days ^{0}C. The results revealed that long term heat unit requirement for the growing season ranges from about 1800 to 2400. Approximately 2200 to 2400 heat units are required for optimum production of cotton (Supak, 1982).

The GDD was significantly reduced compared to normal sown crop. Similar types of results were observed by Young *et al.*(1980) , Hebbar *et al.* (2002) and Prakash *et al.* (2010) who reported that the early sown crop experienced the maximum cumulative growing degree days, whereas, the late sown crop experienced the minimum cumulative growing degree days. Late sowing resulted significantly reduction in the growing degree day.

Literature Cited

Ban, Y.G., Nawalkar, D.P., Mote, B.M., Kumar, V. and Narwade, A.V. 2015.Crop phenology, thermal requirement and yield and fiber properties of cotton *(Gossypium hirsutum)* genotypes as influenced by different environments. Indian J. Plant Physiol. 20 (2): 137–144.

Hebbar, K. B., Venugopalan, M. V., Rao, M. R. K., Gadade, G. D., Chatterji,S. and Mayee, C. D. 2002. Effect of sowing dates and fertilizer levels on phenology, growth and yield of cotton. Indian J. Plant Physiol. 7(4): 380-383.

Hutmacher, B., Keeley, Mark and Delgado Rahul 2002. Heat unit averages and time to mature bolls. CA Cotton review. University of CA cotton web site(http://cottoninfo.ucdavis.edu).

Johnson, I.R. and Thornley, H.M. 1985.Temperature dependence of plant and crop processes.Annals of Botany. 55: 1–24.

Landivar,J.A.Cothren,J.T.and Livingston, S.1996.Development and evaluation of the average five internode length technique to determine time of mepiquat chloride application.pp1153-1156.In:Proc.Beltwide cotton conferences, Nashville, Tenn.9-12 Jan.National cotton council of America,Memphis,Tenn.

Prakash, A. H., Bandyopadhyay, K. K., Gopalakrishnan, N. and Anderson A., and Kumar, A. 2010. Interaction of thermal time and nitrogen levels on growth and productivity of cotton (*Gossypium hirsutum).*Indian J. agric. Sci. 80(8): 704-709.

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

Supak, J.R.1982.Using heat units in the high plains.Western cotton production conf. pp. 14-16.

Young, E. F., Taylor, R. M. and Petersen, H. D. 1980. Day degree units and time in relation to vegetative development and fruiting for three cultivars of cotton. J. Crop Sci. 20: 370-373.