**Bulletin of Environment, Pharmacology and Life Sciences**
Bull. Env. Pharmacol. Life Sci., Vol 8 [5] April 2019 : 09-14

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95


**ORIGINAL ARTICLE** **OPEN ACCESS**

# Study The Phenology Growth and Yield of *Kharif* Cotton In Relation To Agrometeorological Indices Under Different Sowing Dates

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**ABSTRACT**
*A field experiment was conducted during kharif season of 2017 at AICRP on Agrometeorology, VNMKV, Parbhani to study the phenology, accumulated growing degree days, photo thermal unit, helio-thermal unit, heat use efficiency and performance of cotton varieties grown under different sowing dates. The crop was sown on 24 MW took maximum calendar days, growing degree days, photo thermal unit, helio-thermal unit to attend different phonological stages till maturity. The plant height, number of branches per plant, number of boll per plant and seed cotton yield recorded in 24 MW was significantly superior to rest of treatment. The significant reduction in seed cotton yield of timely sown varieties was recorded when sowing was delayed beyond 24 MW. Among the varieties highest seed cotton yield of 1499.9 kg ha$^{-1}$ was recorded in varieties Ajeet-155, which was significantly superior over Ankur (897.5 kg ha$^{-1}$) and Mallika (800.4 kg ha$^{-1}$). Among the varieties Ajeet-155 took highest calendar days growing degree days, photo thermal unit, helio-thermal unit to reach the maturity. The variety Ajeet-155 recorded the highest seed cotton yield at 24 MW sowing as compared to all other sowing dates.*
**KEYWORDS:** Growing degree day, photo-thermal units, rainfall, heat use efficiency and temperature.

Received 13.12.2018 Revised 20.01.2019 Accepted 31.01.2019

## INTRODUCTION

Cotton is an important commercial crop and widely traded commodity across the world. Its yield is sensitive to weather, soil as well as management practices. The unreliability and delay in rainfall is posing serious problem in cotton yield. In the present investigation efforts were made to assess the performance of Bt cotton hybrid in relation to climate and yield under delayed sowing. Response of Bt cotton to dates of sowing indicated that yield reduction to the extent of 18.8 and 54.9 per cent was noticed when sowing was delayed from June to July and further to August, respectively [3,4]. In Maharashtra, cotton cultivated under dry and irrigated farming system. The yield is sensitive to weather, soil as well as management practices. Uncertainties in rainfall and other environmental hazards in dry land farming cause large year to year fluctuation in cotton production and productivity. Among these, temperature plays a key role in almost all biological processes of genotype right from sowing to harvest therefore; any possible understanding of climate-yield relationship of Bt. cotton may help to determine heat use efficiency of Bt cotton to maximize yield potentiality under rainfed environment. Thus, rate of development of Bt. cotton from planting to maturity is a function of radiation use efficiency which is the derived factor of temperature, GDD, HTU and solar radiation.

## MATERIALS AND METHODS

A field experiment was conducted *Kharif* season of 2017 at AICRP on Agrometeorology, VNMKV, Parbhani India is situated at an altitude of 407 m above mean sea level, 19$^{o}$ 15' 28.04'' N latitude and 76$^{o}$ 46' 25.47'' E longitude. The experiment was laid out in split plot design with three replication and 18 treatments combinations consist of 4 dates of sowing and 3 genotypes. The main plot receives 4 dates of sowing *viz*., 24 MW, 25 MW, 26 MW and 27 MW and 3 varieties that is, Ajeet-155, Mallika and Ankur were imposed in sub plots. Seeds were sown manually at 120 X 45 cm spacing in the well prepared field. Meteorological data *viz,* rainfall, relative humidity, maximum and minimum temperature, bright sun shine hrs and day length were recorded from Agro-meteorological observatory of AICRP on Agrometeorology,

VNMKV, Parbhani India.

The Agro-meteorological indices growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU), heat use efficiency (HUE) were calculated using following formula:

**Harvest index:**

It is the per cent of economical yield to the total biological yield. Harvest index reflects the proportion of assimilate distribution between economical and total biomass [2].

It was computed by using following formula:

$$HI = \frac{\text{Total grain yield}}{\text{Total biological yield}}$$

**Heat use efficiency (HUE) [(kg/ha) / $^{o}$C day]**

$$HUE = \frac{\text{Total grain yield (kg/ha)}}{\text{Accumulated GDD ($^{o}$C days)}}$$

**COMPUTATION OF AGRO-METEOROLOGICAL INDICES:**

**Growing degree days (GDD):**

Growing degree days defined as the total amount of heat required between the lower and upper thresholds, for an organisms to develop from one point to another in it's life cycle is calculated in units. The growing degree days (GDD) were worked out by considering the base temperature of 15 $^{0}$C. The total growing degree days (GDD) for different phenophases were calculated by using the following equation:

$$\textbf{Accumulated GDD} = \sum_{ds}^{dh} [(T_{max} + T_{min})/2] - Tb$$

where,

| | | |
|---|---|---|
| GDD | = | Growing degree day |
| Tmax | = | Daily maximum temperature ($^{0}$C) |
| Tmin | = | Daily minimum temperature ($^{0}$C) |
| Tb | = | Base temperature (15 $^{0}$C) |
| Ds | = | Date of emergence |
| Dh | = | Date of harvest. |

**Photo thermal units (PTU):**

PTU = GDD × maximum sunshine hours [5, 7]

**Helio-thermal units (HTU):**

The HTU may be defined as the accumulated product of GDD and bright sunshine hours between the developmental thresholds for each day. The HTU is the product of GDD and the mean daily hours of bright sunshine. The sum of HTU for each phenophases was worked out by using the following equation:

HTU= (GDD × bright Sunshine hours.)

**RESULTS AND DISCUSSION**

**Effect of Rainfall and temperature**

Rainfall and temperatures during vegetative and reproductive stage are presented in (Table 1). Data shows that cotton crop sown under different sowing dates had exposed to various thermal regimes during vegetative and reproductive phase of the crop. It was noted that 24 MW sown crop experienced higher mean temperature during vegetative phase in all three varieties but more rainfall recorded in sown 27 MW. However, during reproductive phase, later sowing dates that is, 24 MW and 25 MW experienced less rainfall, minimum and mean temperatures were recorded and higher maximum temperature , as compared to rest of treatment in all varieties.

**Harvest index:**

The data on harvest index are presented in Table 2 indicated that the mean harvest index was 21.5.

***Date of sowing*:**

Harvest index show much variation and ranged between 17.0 to 40.8 per cent. The sowing date $D_1$ (MW-24) recorded more harvest index *i.e.* 40.8 and it was followed by $D_2$ (MW-25), $D_3$ (MW-26) and $D_4$ (MW-27) *i.e.* 29.0, 18.4 and 17.0, per cent respectively.

***Variety*:**

The cultivar $V_1$(Ajeet-155) recorded more harvest index and ranked first in all genotypes *i.e.* 28.7 and it was followed by $V_3$ (Ankur) and $V_2$ (Mallika). The lowest harvest index was recorded in $V_2$ (Mallika) *i.e.*

25.4.

**Grain yield and straw yield (kg/ha):**

The data regarding grain yield are presented in Table 2.

**Date of sowing:**

The data on seed cotton yield and straw yield indicated that the crop sown in $D_1$ MW-24 recorded higher seed cotton yield (1499.9 kg/ha) and (3672.8 kg/ha) found significantly superior over other treatments whereas the lowest yield was recorded in treatment $D_3$. Over all this year the crop recorded highest yield due to ample soil moisture during crop growing period. Delayed sowing hastened the crop phonological development, thereby causing significant reduction in seed cotton yields Patil *et al.* [6], Ali *et al*.[1] and Waghmare *et al* [11] also reported the similar observation under delayed sowing.

**Variety:**

Statistical analysis of cotton varieties showed significant result. During this year, variety Ajeet-155 ($V_1$) produced higher seed cotton and straw yield (953.9 kg/ha) and (3328.0 kg/ha) found significantly superior over the remaining treatments. Whereas, the variety $V_2$ (Mallika) produced lowest grain yield (800.4 kg/ha).

**Interaction:**

The interaction effect between date of sowing and different varieties was found to be significant of seed cotton yield while non-significant of straw yield and the results to that effect are presented in Table 1.

**Heat use efficiency and Growing degree days (GDD)**

Data in Table 2 & 3 show that the highest HUE for seed cotton yield (0.41 kg/ha/°C days) was recorded under 24 MW sown crop. With respect to varieties, it was noted that Ajeet-155 registered maximum accumulated GDD (3412.9 °C day) followed by Mallika (3391.6 °C day) and Ankur (3395.1 °C day). However, maximum HUE for seed cotton yield was recorded in variety Ajeet-155 and Ankur and lowest HUE was recorded in variety Mallika. The lower HUE in delayed sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stages. but the heat unit required to achieve yields were more or less similar under three varieties.

Date of sowing and different varieties had significant difference in days taken to earing and maturity. The phenologial studies revealed that 24 MW sown varieties took maximum number of days to attain maturity and constantly decreased with subsequent sowing. With delay in sowing, the crop duration was drastically reduced on account of shorter vegetative and reproductive phase. In late sown varieties the duration of crop growth decreased because of forced maturity due to higher mean temperature coupled with low relative humidity. It is an established fact that crop phenology are largely dependent on genetic and environmental factors Viz temperature, relative humidity, sun shine hours, rainfall etc [10]. Significant differences were observed in respect of days taken by the varieties to reach at the various phenological phases and among the varieties Ajeet-155 took longer time to attain the various phonological phases.

**photo-thermal unit (PTU)**

The variation in PTU in different treatments at earing and maturity has been presented in (Table 4). The varieties sown on 24 MW required maximum PTU (49,743.9 °C hrs) till maturity which was superior over 25 MW, 26 MW and 27 MW sown crop at all stages. Ajeet-155 requires maximum PTU (46,172.5 °C hrs)which was significantly superior over Mallika and Ankur. The higher PTU value in early sown crop may be due to fact that crop took longer duration to reach phenological stages. Similar result found that Singh *et al*., [9].

**Helio thermal units (HTU)**

Accumulated Helio thermal units required to attain different phenological stages of cotton varieties are presented in (Table 5). Data shows that the highest Helio thermal unit 20974.5 °C day hours were required for maturity when sown on 24 MW. Ajeet-155 required more helio thermal units for attaining maturity as compared to rest of varieties. This might be due to delayed maturity in early sown as compare to late sown cotton crop. similar result found that Singh *et al*., [9].

**Correlation coefficient**

Correlation coefficient of seed cotton yield with different weather parameters and Agrometeorological indices are presented in (Table 6). Correlation coefficient between seed cotton yield with rainfall, maximum and minimum temperature was highly positively significant while growing degree days, helio thermal units and photo thermal units was negatively correlation of Ajeet-155, Mallika and Ankur varieties. Morning relative humidity was positively correlation of Ajeet-155. Similar result reported of Ratnam *et al* [8].

## CONCLUSIONS

The crop sown on 24 MW took a maximum Heat use efficiency, calendar day, GDD, PTU and HTU for

maturity which got reduced significantly with subsequent delay in sowing time and recorded lowest value on the 27 MW sown crop. The 24 MW recorded the highest seed cotton yield which was statistically significant with rest of sowing date . Highest mean temperature during vegetative and reproductive phase was also under 24 MW sown crop. Among the varieties, variety Ajeet-155 took highest Heat use efficiency, calendar day, GDD, PTU and HTU for maturity. The highest seed cotton yield was recorded in variety Ajeet-155 as compared to Mallika and Ankur.

**Table 1. Rainfall and temperature (°C) during vegetative and reproductive phase**

| Sowing dates | Vegetative | | | | Reproductive | | | |
|---|---|---|---|---|---|---|---|---|
| | Rainfall (mm) | Tmax (°C) | Tmin (°C) | Tmean (°C) | Rainfall (mm) | Tmax (°C) | Tmin (°C) | Tmean (°C) |
| **$V_1$-Ajeet-155** | | | | | | | | |
| **$D_1$ (24 MW)** | 180.4 | 32.9 | 23.2 | 28.1 | 618.6 | 31.8 | 22.5 | 27.2 |
| **$D_2$ (25 MW)** | 157.9 | 33.1 | 23.5 | 28.3 | 605.9 | 31.5 | 22.2 | 26.8 |
| **$D_3$ (26 MW)** | 273.0 | 31.5 | 23.0 | 27.3 | 462.9 | 31.3 | 20.8 | 26.1 |
| **$D_4$ (27 MW)** | 401.0 | 31.2 | 22.8 | 27.0 | 334.9 | 32.0 | 20.3 | 26.2 |
| **$V_2$-Mallika** | | | | | | | | |
| **$D_1$ (24 MW)** | 180.4 | 33.0 | 23.3 | 28.2 | 618.6 | 31.8 | 22.5 | 27.2 |
| **$D_2$ (25 MW)** | 161.3 | 32.9 | 23.4 | 28.2 | 602.5 | 31.2 | 22.3 | 26.8 |
| **$D_3$ (26 MW)** | 273.0 | 31.4 | 23.0 | 27.2 | 462.9 | 31.3 | 20.8 | 26.0 |
| **$D_4$ (27 MW)** | 401.0 | 31.4 | 22.9 | 27.1 | 334.9 | 32.0 | 20.3 | 26.2 |
| **$V_3$-Ankur** | | | | | | | | |
| **$D_1$ (24 MW)** | 180.4 | 33.0 | 23.1 | 28.1 | 618.6 | 31.8 | 22.5 | 27.2 |
| **$D_2$ (25 MW)** | 168.7 | 33.0 | 23.5 | 28.3 | 595.1 | 31.3 | 22.3 | 26.8 |
| **$D_3$ (26 MW)** | 273.0 | 31.4 | 23.0 | 27.2 | 462.9 | 31.3 | 20.7 | 26.0 |
| **$D_4$ (27 MW)** | 401.0 | 31.4 | 22.9 | 27.1 | 334.9 | 32.0 | 30.2 | 26.1 |

**Table 2. Yield of cotton, (Kg ha$^{-1}$) Harvest index (%) and Heat use efficiency as influenced by different treatments**

| Treatments | Seed cotton Yield (Kg ha$^{-1}$) | Straw Yield (Kg ha$^{-1}$) | Harvest index (%) | Heat use efficiency (HUE) (Kg ha$^{-1}$ $^0$C days) |
|---|---|---|---|---|
| **Date of sowing (D)** | | | | |
| **$D_1$ (24 MW)** | 1499.9 | 3672.8 | 40.8 | 0.41 |
| **$D_2$ (25 MW)** | 1038.0 | 3574.2 | 29.0 | 0.30 |
| **$D_3$ (26 MW)** | 497.0 | 2694.2 | 18.4 | 0.15 |
| **$D_4$ (27 MW)** | 505.0 | 2970.8 | 17.0 | 0.16 |
| **SE. ±** | 49.1 | 47.6 | 3.5 | 0.02 |
| **CD. at 5%** | 169.8 | 141.3 | 10.4 | 0.05 |
| **Variety (V)** | | | | |
| **$V_1$ (Ajeet-155)** | 953.9 | 3328.0 | 28.7 | 0.28 |
| **$V_2$ (Mallika)** | 800.4 | 3157.1 | 25.4 | 0.24 |
| **$V_3$ (Ankur)** | 897.5 | 3198.8 | 28.1 | 0.26 |
| **SE. ±** | 14.2 | 34.7 | 0.08 | 0.01 |
| **CD. at 5%** | 42.6 | NS | 0.22 | NS |
| **Interaction (D X V)** | | | | |
| **SE. ±** | 56.9 | 82.4 | 6.8 | 0.02 |
| **CD at 5%** | 170.6 | NS | 20.3 | NS |
| **GM** | 883.9 | 3228.0 | 21.5 | 0.26 |

**Table 3. Effect of date of sowing and varieties on accumulated GDD (°C days) of cotton.**

| Sowing dates | Sowing To Germination | Germination To Square formation | Square formation To flowering | Flowering to boll formation | Boll formation to boll bursting | Boll bursting to picking | Total |
|---|---|---|---|---|---|---|---|
| **Sowing dates** | | | | | | | |
| **$D_1$(24 MW)** | 139.8 | 841.6 | 449.9 | 258.5 | 1172.0 | 812.7 | 3674.5 |
| **$D_2$ (25 MW)** | 143.9 | 913.9 | 382.3 | 133.9 | 1241.8 | 658.7 | 3474.6 |
| **$D_3$ (26 MW)** | 402.9 | 786.5 | 229.2 | 298.2 | 1024.8 | 506.7 | 3256.3 |
| **$D_4$ (27 MW)** | 264.9 | 1013.8 | 312.9 | 177.1 | 936.8 | 496.5 | 3240.3 |
| **SE. ±** | 0.24 | 0.28 | 0.28 | 0.14 | 0.27 | 0.43 | 0.35 |
| **CD. at 5%** | 0.82 | 0.98 | 0.97 | 0.50 | 0.92 | 1.50 | 1.22 |
| **Varieties** | | | | | | | |
| **$V_1$(Ajeet-155)** | 249..9 | 881.0 | 344.3 | 218.2 | 1100.8 | 618.6 | 3412.9 |
| **$V_2$ (Mallika)** | 228.6 | 862.7 | 369.4 | 219.6 | 1080.5 | 630.8 | 3391.6 |
| **$V_3$ (Ankur)** | 235.2 | 923.1 | 317.1 | 213.1 | 1100.3 | 606.5 | 3395.1 |
| **SE. ±** | 0.01 | 0.05 | 0.04 | 0.02 | 0.02 | 0.30 | 0.05 |
| **CD. at 5%** | 0.04 | 0.14 | 0.12 | 0.06 | 0.07 | 0.09 | 0.17 |
| **Interaction (D X V)** | | | | | | | |
| **SE. ±** | 0.04 | 0.19 | 0.16 | 0.07 | 0.09 | 0.12 | 0.23 |
| **CD. at 5%** | 0.14 | 0.56 | 0.49 | 0.24 | 0.26 | 0.37 | 0.69 |
| **GM** | 237.9 | 888.9 | 343.6 | 216.9 | 1093.9 | 618.6 | 3399.9 |

**Table 4. Effect of date of sowing and varieties on accumulated PTU (°C days) of**

| Sowing dates | Sowing To Germinatin | Germination To Square formation | Square formation To flowering | Flowering to boll formation | Boll formation to boll bursting | Boll bursting to picking | Total |
|---|---|---|---|---|---|---|---|
| **Sowing dates** | | | | | | | |
| **$D_1$ (24 MW)** | 1884.7 | 11285.4 | 6119.0 | 3502.2 | 15916.2 | 11036.4 | 49743.9 |
| **$D_2$ (25 MW)** | 1940.1 | 12255.6 | 5199.1 | 1815.3 | 16863.6 | 8944.7 | 47018.4 |
| **$D_3$ (26 MW)** | 5430.5 | 10546.9 | 3117.6 | 4040.6 | 13917.2 | 6880.5 | 43933.3 |
| **$D_4$ (27 MW)** | 3571.2 | 13594.9 | 4256.2 | 2399.7 | 12721.3 | 6742.9 | 43286.1 |
| **SE. ±** | 3.19 | 3.81 | 3.79 | 1.95 | 3.17 | 5.87 | 4.78 |
| **CD. at 5%** | 11.1 | 13.2 | 13.1 | 6.75 | 12.5 | 20.3 | 16.6 |
| **Varieties** | | | | | | | |
| **$V_1$ (Ajeet-155)** | 3368.3 | 11814.5 | 4683.1 | 2956.3 | 14949.2 | 8401.1 | 46172.5 |
| **$V_2$ (Mallika)** | 3081.7 | 11569.4 | 5023.4 | 2975.2 | 14672.9 | 8566.3 | 45888.8 |
| **$V_3$ (Ankur)** | 3169.9 | 12378.2 | 4312.4 | 2886.8 | 14941.7 | 8235.9 | 45925.0 |
| **SE. ±** | 0.16 | 0.63 | 0.55 | 0.27 | 0.30 | 0.41 | 0.77 |
| **CD. at 5%** | 0.47 | 1.88 | 1.65 | 0.81 | 0.89 | 1.24 | 2.32 |
| **Interaction (D X V)** | | | | | | | |
| **SE. ±** | 0.63 | 2.51 | 2.21 | 1.08 | 1.19 | 1.66 | 3.09 |
| **CD. at 5%** | 1.90 | 7.52 | 6.26 | 3.23 | 3.56 | 4.98 | 9.26 |
| **GM** | 3206.6 | 11920.7 | 4672.9 | 2939.5 | 14854.6 | 8401.1 | 45995.5 |

**Table 5. Effect of date of sowing and varieties on accumulated Helio thermal units (°C days)**

| Sowing dates | Sowing To Germination | Germination To Square formation | Square formation To flowering | Flowering to boll formation | Boll formation to boll bursting | Boll bursting to picking | Total |
|---|---|---|---|---|---|---|---|
| **Sowing dates** | | | | | | | |
| **$D_1$ (24 MW)** | 965.1 | 3747.0 | 2363.5 | 1146.7 | 7138.2 | 5613.6 | 20974.5 |
| **$D_2$ (25 MW)** | 936.4 | 4108.9 | 2189.5 | 644.7 | 7406.4 | 4435.0 | 19721.1 |
| **$D_3$ (26 MW)** | 2216.6 | 3408.3 | 1300.4 | 1510.9 | 6379.4 | 3857.6 | 18683.1 |
| **$D_4$ (27 MW)** | 1748.5 | 4154.9 | 1686.7 | 891.4 | 5874.1 | 3773.7 | 18129.3 |
| **SE. ±** | 1.19 | 1.01 | 1.43 | 0.71 | 1.34 | 2.45 | 1.77 |
| **CD. at 5%** | 4.13 | 3.49 | 4.94 | 2.47 | 4.67 | 8.49 | 6.14 |
| **Varieties** | | | | | | | |
| **$V_1$ (Ajeet-155)** | 1482.6 | 3851.2 | 1980.7 | 995.6 | 6637.3 | 4561.5 | 19509.0 |
| **$V_2$ (Mallika)** | 1374.7 | 3943.5 | 1778.5 | 1013.8 | 6762.5 | 4257.8 | 19130.8 |
| **$V_3$ (Ankur)** | 1542.6 | 3769.9 | 1895.9 | 1135.8 | 6698.8 | 4448.0 | 19491.1 |
| **SE. ±** | 0.30 | 0.51 | 0.46 | 0.26 | 0.32 | 0.78 | 0.65 |
| **CD. at 5%** | 0.90 | 1.54 | 1.37 | 0.79 | 0.96 | 2.34 | 1.95 |
| **Interaction (D X V)** | | | | | | | |
| **SE. ±** | 1.20 | 2.06 | 1.83 | 1.05 | 1.28 | 3.12 | 2.60 |
| **CD. at 5%** | 3.60 | 6.16 | 5.49 | 3.16 | 3.83 | 9.35 | 7.79 |
| **GM** | 1466.7 | 3854.9 | 1885.0 | 1048.4 | 6699.5 | 4422.5 | 19376.9 |

**Table 6.Correlation coefficient of Weather parameters, Agrometeorological indices with seed cotton yield.**

| | Rainfall | Tmax | Tmin | RH-I | RH-II | GDD | HTU | PTU |
|---|---|---|---|---|---|---|---|---|
| **Ajeet-155** | 0.993** | 0.944** | 0.856** | 0.853** | 0.040 | -0.780** | -0.746** | 0.712* |
| **Mallika** | 0.987** | 0.913** | 0.595* | -0.487 | -0.404 | -0.887** | -0.765** | -0.889** |
| **Ankur** | 0.986** | 0.956** | 0.839** | -0.141 | -0.014 | -0.790** | -0.646* | -0.846** |

**(* Significant at 5%, ** Significant at 1%)**

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**CITATION OF THIS ARTICLE**

Y. E. Kadam and K. K. Dakhore. Study The Phenology Growth and Yield of *Kharif* Cotton In Relation To Agrometeorological Indices Under Different Sowing Dates. Bull. Env. Pharmacol. Life Sci., Vol 8 [5] April 2019: 09-14