The Pharma Innovation Journal 2022; 11(12): 6079-6083

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 6079-6083

www.thepharmajournal.com
Received: 18-10-2022
Accepted: 22-11-2022

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Agro-meteorological studies on *Bt.* cotton hybrids with different sowing dates under high-density planting in Parbhani (Maharashtra)

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Abstract
Planting density is the most action factor and play vital role in crop management practices. The rational plant population is on important attribute to high yield of cotton production became it can be provided beneficial micro environment within the canopy for plant growth and development as well as yield formation. A field investigation was carried out at the field of Central Farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (MS) during 2021. Three sowing window and two *Bt.* cotton hybrids *viz*., Ajeet-05 and MCS-245 with their plant densities with the population level of 100, 150 and 225 percent of normal for respective *Bt.* cotton hybrids under high density planting laid out in split plot design with their replication.

The result revealed that sowing in 26th MW (D_1) and *Bt.* cotton hybrid i.e., Ajeet-05 with 150 to 225 percent planting density recorded maximum friction of photo synthetically active radiation (PAR), lowest friction of transmitted PAR and canopy temperature with high canopy temperature depression and greater to greater tolerance to environment stress with comparative to MCS-245 and Ajeet-05 recorded significantly higher number of picked bolls, boll weight, higher seed cotton weight and harvest index (17.24 bolls/plant 3.65 g, 12.13g. and 37.96) as compared to MCS-245. However, Ajeet-05 registered significantly higher seed cotton yield, cotton stalk yield and biological yield (1944 kg ha^{-1}, 3172 kg ha^{-1} and 5116 kg ha^{-1}) than MCS-245, normal plant density recorded higher number of picked boll plant^{-1}, seed cotton weight plant^{-1} (20.29 boll plant^{-1} and 75.91 g plant^{-1}), which are significantly more over high plant density of 150 and 225 percent of normal population.

However, normal planting at 150 and 225 percent populations was recorded being at par high density planting (225 percent of normal density) produced maximum seed cotton yield, cotton stalk yield and biological yield i.e., 2024 kg ha^{-1} 3296 kg ha^{-1} and 5320 kg ha^{-1} was pertaining, whereas high density plating at 225 percent of least density produced maximum harvest index (38.00%) which are significantly higher than 100 percent and statistically at par with high density planting of 150 percent.

Keywords: Agro-meteorological studies, *Bt.* cotton hybrids, high-density planting

Introduction
Planting density is the most active factor and plays pivotal role in crop management practices hence plant density is the enduring topic for crop production improvement. Hence increasing plant population could be one of the most effective ways of improving yield this system gained further acceptance after the introduction of *Bt.* cotton hybrids.

Cotton is very sensitive to environmental condition and grown in a wide range of ecological zones and thus a number of factors, sowing time, *Bt.* cotton hybrids, plant densities are involved in cotton yield. Planting date is important to explore the potential of *Bt.* cotton hybrid in the region (Ali *et al.*, 2009) [1]. Early sowing produced 10% more flowers, 23% more open bolls and 18% more seed cotton yield than late sowing (Arshad *et al.*, 2007) [3].

These finding are also supported in other Countries by researcher (Bange *et al.*, 2008) [4], who reported that higher seed cotton yield due to early sowing was mainly attributed to higher boll number, boll weight and seed cotton yield per plant. Similarly cotton yield declines with delay in sowing due to shorter line available to initial and mature an adequate number of bolls. After introduction of *Bt.* cotton hybrids cotton productivity has jumped fore fold in last decodes.

The responses of cotton to plant density are also formed by other researchers and they reported that the highest seed cotton yields were obtained in narrow space crop and row spacing increases total seasonal light interception that can potentially increase cotton yield, results of plant density have also shown that has altered the plant architecture, photosynthetic efficiency of leaves, small boll and fruits production pattern.

With above background and emphasis, the research project was undertaken with following objectives to study the morphology, phenology to understand the relationship between sowing dates and canopy environment in *Bt.* cotton hybrids *viz.*, Ajeet-05 and MCS-245 under high density planting.

Materials and Methods

The field experiment was conducted during *kharif* season of 2021 at the Balsa block, Central farm, VNMKV, Parbhani. The experiment was laid out in split plot design with three replications. The treatment comprising of three Date of sowing i.e., 26th MW, 27th MW and 28th MW), two *Bt.* cotton hybrids i.e., Ajeet-5 (H_1) and MCS-245 (H_2) and three plant spacing i.e., 90 cm x 45 cm, 90 cm x 30 cm and 90 cm x 20 cm. The treatments were randomly allotted in each replication. The gross and net plot sizes were 5.4 m x 5.4 m and 3.6 m x 3.6 m respectively.

The daily observation on air temperature, relative humidity, precipitation and bright sunshine hours were recorded at meteorological observatory. The weather data were used for the analysis. The information about agro-meteorological indices is depending upon the climate, hybrids and soil type of the region where the crop is grown. The following agro-meteorological indices were computed using the daily meteorological data which were taken from agro meteorological observatory. The heat unit concept was initially developed to study plant-temperature relationship and to provide a method for more precisely measuring the intervals between growth stages. The resulting number is the number of heat units accumulated for the day. The method typically used for calculating accumulated heat units is expressed by following formula (Freeland *et al.*, 2004) [6].

$$\text{Accumulated GDD } (^0\text{C day}) = \sum_{ds}^{dh}[(\text{T max} + \text{T min})/2] - T_b$$

Where,

T_{base} - base temperature of crop (15.5 °C or 60 ^{0}F)

ds= Date of sowing

dh= date of harvesting

Day and night are one of the basic factors controlling the periods of vegetative growth in a photosensitive crop. The photothermal units or GDD and day length. The sum of photothermal unit for each phenophase was worked out by using the following formula, (Kumar *et al.*, 2012) [7].

Photochemical Unit (°C day h) = Σ (Heat Units x D)

Where,

D = Day length in hours

The data recorded were statistically analyzed by using technique of ANOVA i.e., analysis of variance and significance was determined as given by Panse and sukhatme (1967) [9]. The statistical analysis worked out with the help of computer.

Result and Discussion

The data given in table 1 shows that the number of growing degree days was accumulated during the each phenol phase at the base temperature of 15.5 °C (60°F) and it was obtained 774° days as general mean. The duration taken from commencement of different phenological event rise emergence to square formation (P_1), square formation to flowering (P_2), flowering to boll formation (P_3), boll flowering to boll bursting (P_4) and boll bursting to maturity (P_5) for different data of season of *Bt.* cotton hybrids more high during planting is given in table 1 and data revealed that 26th MW sowing required significantly highest number of days (160) for attaining various phenophase and lowest (150 days) in 28th MW sowing. Whereas, due to shorter duration on late sown crop yield as well as total biomass production the data also showed that mean number of days required for attaining various phenophase in respect of *Bt.* Cotton hybrids was also influenced by varietal characters. The *Bt.* cotton hybrids MCS-245 was recorded highest days 1241 days for attaining various phenophase than others *Bt.* cotton hybrids i.e., Ajeet-5. It was found to be due to the genotype variation in *Bt.* cotton and which was superior differently to similar weather conditions.

Normally planting density (100%) required comparatively a greater number of days to attain different phenophase and to reach maturity. Plant in the thin stands grow large vegetative structure and more fruits load as a result more lime is required to set the crop and consequently maturity is delayed. There appears marginal difference of 5-8 days between 100-150% plant density and 8-10 days in 225% plant density in attainment of respective phenophase and maturity. In comparison with normal and narrow planting during (100%), 200% plant density population shows earlier flowering (2 days) first boll formation (3 days)., boll bursting (4 days) and final maturity (6 days). According to (Munir *et al.*, 2015) [8] number of days for sowing to first floral bud initiation (squaring) was decreased by narrow spacing, which might be due to increased inter planting competition.

Table 1: Phenophase wise accumulated GDD (°C days) as influenced by different treatment during 2021.

Treatment	P_1	P_2	P_3	P_4	P_5	Mean
Main treatments						
I) Sowing dates						
D_1-26th-MW (25/6/2021 to 01/7/2021)	430.18	552.18	831.63	1124.87	1394.65	866.70
D_2-27th-MW (02/7/2021 to 08/7/2021)	383.74	505.74	736.84	1015.66	1259.40	780.27
D_3-28th -MW (09/7/2021 to 15/7/2021)	342.43	463.67	638.01	861.30	1043.19	669.72
II) *Bt.* cotton hybrids						
H_1 – Ajeet-5	392.96	514.96	735.17	992.80	1223.15	771.80
H_2 – MCS-245	377.43	499.43	735.81	1008.42	1241.67	772.55
Sub treatment						
I) Plant spacing (cm)						
S_1 - 90 x 45 cm2 (24,691 plants ha^{-1})	391.97	513.97	742.47	1007.49	1238.78	788.05
S_2 - 90 x 30 cm2 (37,037 plants ha^{-1}))	385.27	507.27	733.74	1003.91	1230.91	772.22
S_3 - 90 x 20 cm2 (55,555 plants ha^{-1})	378.34	540.34	730.27	990.43	1227.54	773.38
G Mean	385.29	512.20	642.68	1000.61	1232.41	774.59

Photothermal unit (°C day hours)

Photothermal unit is the agro meteorological indices that mean how much quantity of heat energy to be used by the plant during the day. It is calculated by multiplying the daily heat units or GDD with the length of day. The number of photothermal units to be accumulated by the crop during its life cycle at different phenophase are given in the table 1. The photothermal units was influenced by the numbers of days required for recording to each phenophase or to complete life cycle during average temperature and length of the day.

Above Table 1 showed the number photothermal units was showed accumulated during each phenophase at the base temperature of 15.5 °C was significantly influenced by different sowing dates. The data revealed that average photothermal units accumulated during different sowing was observed 3521 °C day hrs. The highest number of photothermal unit was recorded in 26th MW sowing (9160 °C day hrs.) followed by 27th MW sowing (8967 °C day hrs.) and lowest in 28th MW sowing (9028 °C day hrs.) due to continuous rain in the month of September to October 2021.

While, the highest number of photothermal units were recorded in 26th MW sowing at all the phenophase and lowest in 27th MW sowing. However, within all crop growth stages the highest number of photothermal units record at boll formation to boll bursting stage (P_4). The lowest number of photothermal units was accumulated at square to flowering stage in all the sowing dates.

However, among the different *Bt.* cotton hybrids the photothermal units was significantly influenced and the mean photothermal units accumulated was observed 3492 °C day hrs. while, it was found that the highest number of photothermal units (3519 °C day hrs.) was recorded in the Ajeet-05 and lowest in MCS-245 (3465 °C) in all sowing dates.

Crop grown with normal plant density (NP-100%) accumulated higher thermal units (9027 °C day hrs.) follow by high plant density i.e., 150% (8930 °C day hrs.) and 225% (8830 °C day hrs.) comparatively larger total growth duration of the crop in the respective *Bt.* cotton hybrids accumulated of thermal units.

Table 2: Phenophase wise accumulated Heliothermal units as influenced by different treatment during 2021.

Treatment	P_1	P_2	P_3	P_4	P_5	Mean
Main treatments						
I) Sowing dates						
D_1 -26th - MW (25/06/2021 to 01/07/2021)	759	1318	1539	4616	9160	3478
D_2 -27th - MW (02/07/2021 to 08/07/2021)	809	1430	1632	4677	8967	3503
D_3 -28th - MW (09/07/2021 to 15/07/2021)	859	1591	1792	4770	9028	3608
II) *Bt.* cotton hybrids						
H_1 – Ajeet-5	772	1389	1602	4880	8954	3519
H_2 – MCS-245	754	1369	1577	4810	8817	3465
Sub treatment						
I) Plant spacing (cm)						
S_1 - 90 x 45 cm^2 (24,691 plants ha^{-1})	860	1492	1697	4880	9027	3591
S_2 - 90 x 30 cm^2 (37,037 plants ha^{-1})	828	1462	1660	4810	8930	3538
S_3 - 90 x 20 cm^2 (55,555 plants ha^{-1})	817	1392	1598	4720	8830	3471
G Mean	807	1430	1637	4770	8964	3521

P_1 – Emergence to square formation P_2 – Square formation to flowering stage,
P_3 – Flowering to boll formation, P_4 – Boll formation to boll bursting.
P_5 – Boll bursting to maturity

Effect of sowing dates, *Bt.* cotton hybrids and plant density on yield parameters

Number of bolls harvested per plant as influenced by various treatments. The average bolls per plants were recorded 16.29. sowing on D_1 (26th MW) was significantly superior over 28th MW (D_3) and 27th MW(D_2). *Bt.* cotton hybrid Ajeet-5 (H_1) recorded significantly higher number of bolls per plant i.e., 17.24. followed by hybrid MCS-245 (H_2). Interaction effect was found to be non-significant in respect of number of picked bolls $plant^{-1}$.

Data in respect of boll weight per plant influenced the average boll weight (g) during crop growing season. The highest boll weight (3.74 g) was recorded in 26th MW (D_1) followed by rest sowing dates. *Bt.* cotton hybrid Ajeet-5 (H_1) recorded maximum average boll weight 3.65 (g) than MCS-245 *Bt.* cotton hybrid (H_2). A plant spacing of 90 cm × 45 cm (S_1) produced more boll weight 3.73 (g) over the plant spacing of 90 cm × 20 cm (S_3) and 90 cm × 30 cm (S_2). Interaction effect was found to be non-significant in respect of average boll weight (g).

Seed cotton yield per plant found to be significant with different date of sowing. It was observed that the sowing date D_1 (26th MW) significantly more seed cotton yield $plant^{-1}$ i.e., 69.62 than D_2 and D_3. Seed cotton yield per plant found to be significant with different hybrids. It was recorded that the *Bt.* cotton hybrid Ajeet-5 (H_1) significantly more seed cotton yield per plant 62.13 g than *Bt.* cotton hybrid MCS-245 (H_2).

Among all sowing dates the significantly highest Seed cotton yield ha^{-1} recorded in 26th MW (D_1) sowing (2055 kg ha^{-1}) and it was found to significantly superior over 27th MW (D_2) and 28th MW (D_3). *Bt.* cotton hybrid Ajeet-5 (H_1) with lower plant spacing of 90 cm x 20 cm (S_3) produces the highest seed cotton yield as compared to *Bt.* cotton hybrid MCS-245 (H_2).

Table 3: Number of picked bolls plant^{-1}, boll weight (g), seed cotton yield (g) plant^{-1} and seed cotton yield (kg ha^{-1}) in *Bt.* cotton hybrid of different treatment during 2021

Main treatments	No. of picked boll plant^{-1}	Boll weight (g)	Seed cotton yield (g) plant^{-1}	seed cotton yield (Kg ha^{-1})
I) Sowing dates				
D_1-26th-MW (25/6/2021to 01/07/2021)	18.99	3.74	69.62	2055
D_2-27th-MW(02/7/2021to 08/07/2021)	16.27	3.59	58.31	1885
D_3-28th-MW (09/7/2021to 5/07/2021)	13.61	3.56	48.88	1792
S.E (m)	0.23	0.03	0.86	8.31
C.D at 5%	0.72	0.10	2.72	26.17
II) *Bt.* cotton hybrids				
H_1 – Ajeet-5	17.24	3.65	62.13	1944
H_2 – MCS-245	15.34	3.62	55.74	1877
S.E (m)	0.19	0.03	0.70	6.78
C.D at 5%	0.59	NS	2.22	21.37
B) Sub treatment				
I) Plant spacing				
S_1 - 90 x 45 cm^2 (24,691 plants ha^{-1})	20.29	3.73	75.91	1739
S_2 - 90 x 30 cm^2 (37,037 plants ha^{-1})	16.49	3.64	58.44	1970
S_3 - 90 x 20 cm^2 (55,555 plants ha^{-1})	12.09	3.52	42.46	2024
S. E. (m) ±	0.17	0.04	0.75	25.73
C. D. at 5%	0.48	0.10	2.19	75.09
I) Interaction Effect				
D x H				
S. E. (m) ±	0.32	0.05	1.22	11.75
C. D. at 5%	NS	NS	NS	NS
D x S				
S. E. (m) ±	0.29	0.06	1.30	44.56
C. D. at 5%	NS	NS	NS	NS
H x S				
S. E. (m) ±	0.23	0.05	1.06	36.38
C. D. at 5%	NS	NS	NS	NS
D x H x S				
S.E (m)	0.41	0.09	1.84	63.01
C.D.at 5%	NS	NS	NS	NS
G Mean	16.29	3.63	58.94	1911

Correlation studies

The correlation coefficient between seed cotton yield and weather parameters were assessed during the experimental year and presented in table 1. positive and highly significant correlation was observed between seed cotton yield and weather parameters *viz.* rainfall (mm), Tmax (°C), Tmin (°C), Tmean (°C), RH-I (%), RH-II (%), Evp (mm), BSS (Hrs.) WV (kmph) at all growth stages during 2021 indicating as the rate of the weather parameters were increased. The yield of seed cotton yield also increased. The correlation between seed cotton yield at different sowing, *Bt.* cotton hybrids and high-density planting with different phenophase are given in the table 1. The most essential growth stages during the cotton seed yield are square formation to flowering (P_2), Flowering to boll formation (P_3) and Boll formation to boll bursting (P_4). Weather parameters *viz.* rainfall, maximum, minimum and mean temperature, morning and evening relative humidity were positively correlated during early growth stages i.e., from square formation to boll development.

While, the correlation results revealed that the weather parameters significantly influenced the growth stages of the crop and finally influenced the seed cotton yield. The result revealed that the rainfall was significantly positively correlated to early growth stages i.e., emergence to square formation (P_1-P_3) and significantly negatively corelated during flowering to boll formation (P_3), while it was found positively and highly significant at boll development stage (P_4). It means that the rainfall distribution was affecting on yield throughout the growing period of cotton at boll bursting and harvesting positive in part was observed. The rainfall found to be statistically significant with positive direction from planting to boll maturity phase.

Temperature also plays a major role in deciding the length of growth stages. The very high and very low temperature ceases the detrimental effect on the crop growth and development. The data in table1 revealed that the maximum, minimum and mean temperature was positively correlated during the early growth stages i.e., emergence to square formation and flowering to boll formation stage and significantly negatively correlated at boll formation to boll bursting and boll bursting to maturity stages. However, the highly positively significant correlation was found on maximum temperature at square formation to flowering stage. In maximum temperature at emergence to flowering stage (P_1-P_2) as well as highly significant negative positive at boll formation to boll bursting (P_3-P_4).

While morning relative humidity (RH-I) showed that the positively significant correlation at P_2-P_5 and afternoon relative humidity (RH-II) showed that positively highly significant at P_1-P_2 and positively significant at P_3-P_5. The evening relative humidity was positively highly significant at square formation to boll formation (P_2-P_4).

Sawan (2013) [10] also reported that minimum relative humidity had positive correlation with flowering to boll development (P_2-P_4). It means that the evaporation and wind velocity negatively significant correlated at P_4 i.e., boll formation to boll bursting.

Wind speed can also stress the cotton plant enough to reduce seed cotton yield, although some wing may beneficial in very hot humid conditions, wind modified the temperature and humidity gradient around the evaporative demand. The result of analysis showed that the bright sunshine hrs was not significantly influencing the crop growth stages during the growing period of 2021.

Table 4: correlation between weather parameters and different growth stages as influenced by different phenophase during 2021.

Weather parameters	P_1	P_2	P_3	P_4	P_5
Rainfall (mm)	0.424**	0.514**	-0.226	0.507**	0.434**
Max. T (°C)	0.313*	0.403**	-0.335*	0.511**	0.492**
Min. T (°C)	0.355**	0.445**	-0.496**	-0.149	0.492**
T mean	0.419**	0.509**	0.342*	0.461**	0.498**
RH. I (%)	0.082	0.172	-0.503**	0.496**	0.477**
RH. II (%)	0.045	0.135	0.511**	0.505**	0.456**
R mean	0.194	0.284*	-0.443**	-0.127	-0.375*
Evp (mm)	0.279*	0.369**	0.345*	-0.510**	0.511**
BSS (Hrs)	-0.070	0.020	0.027	-0.503**	0.503**
WV (Kmph)	-0.027	0.063	0.429**	0.345*	-0.456**

*Significantly at 5% level (r = 0.468)
**Significantly at 1% level (r = 0.590)
P_1 – Emergence to square formation P_2 – Square formation to flowering stage,
P_3 – Flowering to boll formation, P_4 – Boll formation to boll bursting.
P_5 – Boll bursting to maturity

Conclusion

Based on one year data it can be revealed that the 26th MW (D_1) i.e., first sowing with Ajeet-5 *Bt.* cotton hybrid and plant spacing 90 cm x 30 cm (S_2) obtained higher seed cotton yield as compared to MCS-245 *Bt.* cotton hybrid. Ajeet-5 *Bt.* cotton hybrid found productive and gainful at Parbhani location.

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