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EFFECT OF SOWING WINDOWS ON GROWING DEGREE DAYS, THERMAL USE EFFICIENCY AND YIELD IN COTTON

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ABSTRACT

A field experiment was carried out at field of integrated farming system research Dr.PDKV, Akola during *kharif* season of 2016-2017 on clayey soil. The experiment was laid out in Factorial randomized block design with four replications. There were nine treatment combinations comprising of three different genotypes *viz.,* Ajeet-199, AKA-8 and PKV-Rajat and three different dates of sowing ie. 21st May, 15th June and 15th July. Among the different sowing dates D_1, D_2 and D_3, it was found that cotton crop sown under 20 M W (21st May) accumulated highest growing degree days (2190^{0}C day) to reach various phenophase, availed higher HTU (13021^{o}C day hour) and more thermal use efficiency. Seed cotton yield was more with 20 MW (0.82 kg ha^{-1} ^{o}C day $^{-1}$) and also in terms of biological yield. Cotton genotypes Ajeet-199 recorded significantly higher seed cotton yield and also high benefit : cost ratio (2.80).

(Key words: Sowing windows, growing degree days , thermal use efficiency)

INTRODUCTION

India is the largest cotton growing country in the world with area under cotton around 34% followed by China. China and India are the major cotton producing country in the world (around 46% of world cotton production). As regards export USA and India export 28% and 20% of the world cotton export.

In India, Maharashtra rank first in averages with 38.28 lakh ha with 71.25 lakh bales production and average productivity of 342 kg lint ha^{-1}, which is lowest as compared to national average of 503 kg lint ha^{-1}. Important tools for stepping up the production and productivity of cotton in this area are use of high yielding varieties /hybrids, optimum sowing time, cropping system, fertilizer application and proper plant protection .

Important strategy is to analyze crop yield and quality in an environment (Campbell and Jones, 2005). High cotton yield could not be obtained previously due to many biotic and abiotic stresses such as weed infestation, insect pests and diseases, sowing too early or too late, nutrients stress and improper use of genotypes at different agro-ecological zones (Arshad *et al*., 2007; Zia-ul-Hassan *et al*., 2014). Optimum sowing date plays key role in yield potential; similarly, suitable genotype for a region is essential for optimum growth and development. Genotype selection and sowing date management are important factors that can have a large impact on yield and quality attributes of a cotton crop (Deho *et al*., 2012). These two factors mostly limit cotton growth, yield and quality as growth is a function of the product of genotype and environment (Sarwar *et al*., 2012). Optimum sowing time for different genotypes varies with regions depending on environmental conditions of the area. Cotton genotype is mainly selected for higher yield plus fiber quality, greater tolerance to adverse conditions and earlier maturity.

Potential genotypes for higher yield and quality traits could be assessed by sowing them at different times i.e. early, late, and normal time. Both late and early sowing adversely affect cotton yield and quality. Research results revealed that early sown cotton contributes more towards vegetative growth rather than to yield (Iqbal *et al*., 2012).Moreover, early sown cotton reaches reproductive phase in the hottest month of the year that causes serious yield loss (Rahman *et al*., 2007). Contrary to this, late planting causes flowering and maturity when temperature is much cold. Consequently, cotton yield and quality is affected due to unfavourable environmental conditions and shorter growth period (Elayan *et al*., 2015). Karavina *et al*.(2012) reported that change in sowing date not only affects cotton yield and quality but it also affects insect pest management. Therefore, sowing date management has become more important in recent farming. Optimum sowing date provides sufficient time for crop to complete its vegetative and reproductive cycle in a timely and efficient way. This also allows the grower to harvest crop in time and save from risk

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of late season insect pest attack particularly from those insects which attack on reproductive structures causing about 80% damage to cotton (Pedigo, 2004).

Although cotton pests can be effectively controlled with pesticides, however, over use of pesticides is not eco-friendly and leads to killing of beneficial insects and develops resistance in the harmful insects (Karavina *et al*., 2012). Some genotypes have the potential to resist insect pest and perform better in a specific environmental conditions such as temperature, rainfall, humidity, and day length. Therefore, it needs constant efforts to match genotype with suitable time of sowing in an environment in which all the components of climate are in the best favour of crop growth and development. Moreover, cotton genotypes are highly responsive to their surrounding environments and differ in their yield potential and many fiber properties. Thus, it is important to study interaction of sowing date and genotype to determine optimum sowing date for enhancing cotton yield and quality.

Keeping the above aspects in mind this field experiment on effect of sowing windows on growing degree days, thermal use efficiency and yield in cotton was carried out during *kharif* season of the years 2016-17 at IFSR unit Dr.P.D.K.V., Akola.

MATERIALS AND METHODS

A field experiment was carried out at field of integrated farming system research Dr.P.D.K.V, Akola during *kharif* season of 2017 on clayey soil. In the present investigation three sowing times (20 MW- 21st May, 24 MW- 15th June, 28 MW -15th July) were undertaken to create a different set of environmental conditions in three genotypes Ajeet-199 (V_1), AKA-8 (V_2) and PKV-Rajat (V_3). The experiment was laid out in factorial randomized block design with four replications consisting of nine treatment combinations in each. All the cultural operations were carried out in experiment plot to maintain a healthy crop. Observations on seed cotton yield plant^{-1} (g), seed cotton yield (kg ha^{-1}), stalk yield plant^{-1} (g), cotton stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}), harvest index (%), lint yiel (kg ha^{-1}) were recorded. Benefit :Cost ratio for each treatment was also calculated. Observations on growing degree days (^{o}C day), heliothermal units (^{o}C day hour), thermal use efficiency (kg ha^{-1} D^{o}C) in terms of seed cotton yield and biological yield were estimated using the following formulas:

Growing degree days (GDD) were calculated by formula developed by Jones and Wells (1998)

$$\text{GDD (0C day)} = \frac{(\text{T max.} \pm \text{T min})}{2} \text{ X T base}$$

Tmax - Daily maximum temperature (^{0}C)

Tmin - Daily minimum temperature (^{0}C)

Tb - Base temperature as 15.5 ^{0}C for cotton crop

Heliothermal units (HTU), the product of GDD and corresponding actual sunshine hours (SS) for that day were computed on daily basis. Heliothermal units were accumulated from the date of sowing to a particular date of phenophase and from that accumulated HTU for each phenophase and total HTU over the crop period in each treatment were computed.

Heliothermal units calculated by the following formula.

HTU (^{0}C day hour) = " (GDD X SS)

Where,

HTU - Heliothermal units

GDD- Growing degree days

SS - Actual sunshine hours

Thermal use efficiency of crop in terms of seed cotton yield was worked out in all the treatment by dividing the seed cotton yield by respective thermal unit, so as to know the amount of seed yield day^{-1} degree Celsius.

$$\text{Thermal use efficiency (kg ha}^{-1}\text{D}^{o}\text{C)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Thermal requirement (D}^{o}\text{C)}}$$

Thermal use efficiency of crop in terms of biomass under each treatment was calculated from the thermal requirement and biomass production in the respective treatment, as under.

$$\text{Thermal use efficiency (kg ha}^{-1}\text{D}^{o}\text{C)} = \frac{\text{Biological yield (kg ha}^{-1}\text{)}}{\text{Thermal requirement (D}^{o}\text{C)}}$$

The experimental data collected during the course of investigation were statistically analyzed with Factorial Randomized Block Design (Gomez and Gomez, 1984). Wherever, the results were significant, critical differences at P = 0.05 levels were calculated for comparison of treatment means. Data on interaction effects are presented wherever found significant.

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RESULTS AND DISCUSSION

Growing degree days as influenced by sowing dates and genotypes

Data regarding phenophase wise accumulated growing degree days are presented in table 1. The various sowing times and genotypes showed wide variation for accumulated GDD.

Effect of date of sowing

It is evident from the data presented in table 1, that at sowing to square formation stage the early sowing time D_1(20 MW- 21st May) recorded highest accumulated GDD (785), it was followed by D_2 (24 MW- 15th June) where the accumulation of GDD was 573. At this stage the lowest accumulation of GDD (496) was found with sowing time D_3

(28 MW -15th July). At sowing to 50% flowering stage the same trend of treatment was noticed with respective values of 1251, 1022 and 905. At sowing to 50% boll bursting stage maximum accumulation of GDD (1744) was observed with treatment D_1 (20 MW- 21st May), it was followed by treatment D_2 (24 MW- 15th June) and D_3 (28 MW -15th July) with respective values of 1475 and 1305. Finally at sowing to crop maturity stage the maximum amount of accumulated GDD (1930) was recorded with early sowing dates D_1(20 MW- 21st May), it was followed by next sowing dates D_2(24 MW- 15th June) with accumulated GDD value of 1642. Notably lowest accumulated of GDD (1380) was registered with last sowing dates D_3(28 MW -15th July). Thus, from the above data it can be inferred that the early sowing during 21stmay can accumulate the maximum GDD, which subsequently get reduced with delay in the date of sowing. From the period sowing to square formation various genotype recorded moderate differences for the accumulation of GDD. Among the three genotypes maximum accumulation of GDD 640 was observed with V_3(PKV-Rajat) which was followed by V_1(Ajeet-199) and V_2(AKA-8). From sowing to 50% flowering stage genotype AKA-8 was found more promising in accumulation of GDD (1081), which was followed by genotype PKV-Rajat and Ajeet-199. From sowing to 50% boll bursting till the maturity of cotton crop, genotype PKV-Rajat was found to be better as compared to remaining two genotypes by recording the total GDD of 1668. This was followed by genotype Ajeet-199, AKA-8 at maturity which recorded GDD of 1656 and 1631 respectively. Thus, it can be concluded that the accumulation of GDD among various genotypes varies mostly up to 50% boll bursting stage subsequently, the difference in the accumulation of GDD become narrows at the time of maturity.

Heliothermal unit as influenced by sowing dates and genotypes

Heliothermal unit are the function of growing degree days and bright sunshine hours. Remarkable difference among the various sowing dates were observed at various phenological growth stages of cotton crop. At sowing to square formation stages the maximum availability of (5843) heliothermal unit was recorded with sowing time D_1 (20 MW- 21st May) as observed from table 1. Whereas drastic reduction in availability of accumulation HTU was found with sowing time D_3 (28 MW -15th July). From sowing to 50% flowing stages first sowing time D_1 (20 MW- 21st May) availed 7203 HTU, while the last data of sowing D_3 (28 MW -15th July) was exposed to the accumulation HTU valves of 4176. Similar trend of observation was recorded at sowing to 50% boll bursting stages of sowing to maturity the early sowing date D_1 (20 MW- 21st May) availed total HTU of 10833 as compared to the middle and last sowing date D_3 (28 MW -15th July) , where the respective values were 8345 and 7878. The maximum accumulation of HTU with earlier sowing date can be as described to longer period to which the crop was exposed. Among various genotypes, PKV-Rajat (V_3) accumulated maximum HTU of 3563 for the period from sowing to square formation, it was followed by genotype Aject-199 (V_1) and AKA-8 (V_2) with respective values of 3482 and 3239 respectively. However, at the time of sowing to 50% flowering stages genotype AKA-8 recorded maximum accumulation of HTU (5368) which was followed by genotypes PKV-Rajat (V_3) and Ajeet-199 (V_1) respectively. Conversely till the stages of 50% boll bursting and maturity genotype PKV Rajat received maximum HTU (9114) at the stage of maturity. It was followed by genotypes PKV-Rajat (V_3) and AKA-8 (V_2) with respective values of 9046 and 8910 respectively.

Photothermal unit as influenced by sowing dates and genotypes

Photo thermal unit availed to which various growth stages noticeably differ among sowing time. In general the earlier sowing date D_1 (20 MW- 21st May) received highest PTU decrease remarkably with the delay in sowing time. Across the various phenophase of cotton maximum accumulation of PTU were observed during the first phenophose i.e. sowing to first square formation among different sowing dates. The accumulation PTU with the sowing dates of 21st May (D_1) was 24754 which was highest as compared to the sowing dates of 15th June (D_2) and 15thJuly(D_3), where the respective values were 21517 and 15556. During first phenophose *ie.* sowing to first square formation genotype PKV- Rajat (V_3) received maximum accumulation PTU (8644) as compared to genotypes Ajeet-199 (V_1) and AKA-8 (V_2) where the respective values of accumulation PTU were 8448 and 7858 respectively. While at the stage of sowing to 50% flowering genotype AKA-8 received maximum accumulation PTU (13898) which was followed by genotypes PKV- Rajat (V_3) and Ajeet-199 (V_1). However, at sowing to 50% boll bursting stage the accumulation PTU with genotype Ajeet-199 (V_1) recorded minimum value *i.e.* 17987. At the time of maturity the total accumulation PTU was maximum (20826) with genotype PKV- Rajat (V_3). The next best genotype was Ajeet-199 (V_1) which received accumulation of 20670 followed by AKA-8 (V_2) which registered PTU 20359 at this stage. The response of various genotypes to accumulation of PTU varied mostly accumulation to the phase required to complete the phenophose by specific genotype. However, the narrow differences observed for accumulation of PTU thus, depict the similarity in attaining the maturity among the three genotypes under stages. In accordance to this result Waghmare *et al*. (2016) reported the PTU (photo thermal unit) was significantly influenced by different treatments of sowing dates and different hybrids in cotton. The highest number of PTU was accumulated in 25th MW sowing followed by 26th sowing MW sowing. The lowest number of PTU was recorded in 28th MW sowing. Among the hybrids the highest number of PTU recorded in Ajit-155 and Bunny Bt, while lowest PTU recorded in Rashi-779.

Thermal use efficiency (TUE) as influenced by sowing dates and genotypes

The value of thermal use efficiency in terms of seed yield and biological yield, are presented in table 2.

Among the different sowing dates maximum thermal use efficiency in yield (0.82) was observed with first date of sowing *ie*. 21st May (D_1), it was followed by its second date of sowing *ie.* 15th June where the TUE was recorded to be 0.79. Among the different genotypes studied for thermal use efficiency in term of seed yield, TUE was found to be maximum (0.84) with genotype Ajeet-199. This was closely followed by genotype AKA-8 (0.83). Contently the lowest TUE in terms of seed yield (0.66) was noted with PKV- Rajat. Thermal use efficiency in terms of biological yield revealed that genotype AKA-8 improved the status of TUE with respective value of 2.15. Ajeet-199 and PKV- Rajat recorded the TUE values of 2.07 and 1.72. By and large the interaction of AKA-8 and first date of sowing (21st May) remarkable improved the thermal use efficiency in terms of seed yield (0.88).

Yield studies

Data pertaining to seed cotton yield plant^{-1} as influenced by different treatments are presented in table 3. On an average seed cotton yield plant^{-1} was 56.14 g. Seed cotton yield plant^{-1} was found to be significant with different dates of sowing. It was observed that the sowing date 21st May significantly gave more seed cotton yield plant^{-1} (62.56g) than 15th June and 15th July sowing dates. Data regarding seed cotton yield plot^{-1} was found to be significant with different varieties. It was observed that the Bt hybrid Ajeet 199 (V_1) significantly gave more seed cotton yield plant^{-1} (87.84g) than AKA-8 and PKV-Rajat. Interaction effect was found significantly influenced on seed cotton yield plant^{-1}. The treatment combination (D_1V_2) sowing date 21st May with variety Ajeet 199 produced significantly higher seed cotton yield of 95.77g than all other treatment combinations. The lowest yield of 28.08g was recorded in treatment combination of D_3V_2 (sowing date 15th July with variety AKA-8).

Seed cotton yield kg ha^{-1} was found to be significant with different dates of sowing. Early sowing date (21st May) significantly recorded high seed cotton yield of 2962 kg ha^{-1} than15th June and 15th July sowing dates. Seed cotton yield ha^{-1} was found to be significant with different varieties. It was observed that the Bt hybrid Ajeet 199 (V_1) meaningfully gave extra seed cotton yield of 2801 kg ha^{-1} than AKA-8 and PKV-Rajat. Interaction effect was found to be statistically and significantly influenced for seed cotton yield plant^{-1}. The treatment combination (D_1V_2) sowing date 21st May with variety AKA-8 produced significantly higher seed cotton yield of 3134 kg ha^{-1} than all other treatment combinations. The lowest yield was recorded in treatment combination of D_3V_3 (sowing date 15th July with variety PKV-Rajat).

The data on cotton stalk yield plant^{-1} as influenced by different treatments are presented in table 3. The average cotton stalk yield plant^{-1} was 85.66 g. Cotton stalk yield plant^{-1} was found to be significant with different dates of sowing. It was observed that sowing at 21st May gave significantly more cotton stalk yield plant^{-1} (92.33 g) over sowing date 15th July and found at par with 15th June date of sowing which were at par with each other. Cotton stalk yield plant^{-1} was found to be imperative with dissimilar varieties. It was detected that the variety Ajeet 199 (V_1) gave significantly more cotton stalk yield plant^{-1} (130.33 g) than PKV-Rajat (V_3) and AKA-8 (V_2). Interaction effect was influenced statistically significant on cotton stalk yield plant^{-1}. The treatment combination (D_1V_2) sowing date 21st May with variety Ajeet 199 produced significantly higher cotton stalk yield plant^{-1} of 142.50 g than all other treatment combinations. The lowest yield of 39.25 g was recorded in treatment combination of D_3V_2 (sowing date 15th July with variety AKA-8).

The data on cotton stalk yield ha^{-1} as influenced by different treatments are presented in table 3 . The average cotton stalk yield was 4026 kg ha^{-1}. Cotton stalk yield ha^{-1} was found to be significant with different dates of sowing. It was observed that sowing at 21st May gave significantly more cotton stalk yield ha^{-1} (4351) over sowing date 15th July and found at par with 15th June date of sowing. Data regarding cotton stalk yield ha^{-1} was found to be significant in genotypes. It was detected that the genotype AKA-8 (V_2) gave significantly more cotton stalk yield ha^{-1} (4682) than Ajeet-199 (V_1) and PKV-Rajat (V_3), this might be due to the high plant population ha^{-1} in AKA-8 genotype. Interaction effect was found statistically and significantly influenced on cotton stalk yield ha^{-1} . The treatment combination D_2V_2 ie. sowing date 15thJune with variety AKA-8 produced significantly higher cotton stalk yield (5617 kg ha^{-1}) than all other treatment combination. The lowest cotton stalk yield ha^{-1} was recorded in treatment combination of D_3V_3(sowing date 15th July with variety PKV-Rajat).

Data pertaining to biological yield ha^{-1} as influenced by different treatments are presented in table 3. On an average biological yield plot^{-1} was 6841.12 kg. Data regarding biological yield kg ha^{-1} was found to be significant with different dates of sowing. It was noticed that the sowing date 21th May significantly added seed cotton yield of 7550 kg ha^{-1} than15th June and 15th July. It was observed that the genotype AKA-8 (V_2) meaningfully registered extra seed cotton yield than Ajeet 199 (V_1) and PKV-Rajat (V_3). Interaction effect (D x V) was found statistically non-significant in terms of biological yield ha^{-1}.

Data pertaining to Harvest Index (%) as influenced by different treatments are presented in table 3. General mean of harvest index was found to be 38.17 (%). It was observed that effect of sowing date on harvest index was found to be non-significant. It was observed that the variety, AKA-8 (V_2) noted importantly additional harvest index than PKV-Rajat (V_3) and Ajeet199 (V_1), whereas V_3 was found at par with V_1. Interaction effect among different sowing dates and genotypes was found to be non-significant in respect to harvest index.

The relevant data on lint yield ha^{-1} under different treatments are presented in table 3. The average lint yield was recorded to be 847.60 kg ha^{-1}. The different sowing

Table 1. Effect of different treatments of the cotton on Accu. GDD (°C day), Accu. HTU (°C day), Accu. PTU (°C day) and Thermal use efficiency in terms of seed yield (kg ha^{-1} °C day^{-1})

Treatments	Accu. GDD (°C day)				Accu. HTU (°C day)				Accu. PTU (°C day)			
	Sowing to squaring	Sowing to 50% flowering	Sowing to 50% boll bursting	Sowing to maturity	Sowing to squaring	Sowing to 50% flowering	Sowing to 50% boll bursting	Sowing to maturity	Sowing to squaring	Sowing to 50% flowering	Sowing to 50% boll bursting	Sowing to maturity
A) Sowing Dates												
D_1- 21st May (20th MW)	785	1251	1744	1930	5843	7203	9853	10833	11178	17113	22778	24754
D_1- 15th June (24th MW)	573	1022	1475	1642	2447	4400	6905	8345	7695	12981	17857	21517
D_1- 15th July (28th MW)	496	905	1305	1380	2032	4176	7242	7878	6175	10759	14811	15556
B) Varieties												
V_1. Ajeet 199 (90 x 30 cm)	625	1027	1467	1656	3482	5100	7786	9046	8448	13203	17987	20670
V_1. AKA-8 (60 x 15 cm)	582	1081	1558	1631	3239	5368	8057	8910	7858	13898	18613	20359
V_1. PKV Rajat (60 x 30 cm)	640	1067	1544	1668	3563	5301	8192	9114	8644	13725	18926	20826
GM	**617**	**1059**	**1508**	**1651**	**3434**	**5258**	**8027**	**9021**	**8333**	**13613**	**18495**	**20613**

Table 2. Thermal use efficiency in terms of seed yield (kg ha^{-1} °C day^{-1}) at different treatments in cotton

Varieties	Sowing date			
	D_1- 21st May (20th MW)	D_1- 15th June (24th MW)	D_1- 15th July (28th MW)	**Mean**
V_1. Ajeet 199	0.87	0.84	0.82	0.84
	2.09	**2.08**	**2.06**	**2.07**
V_1. AKA-8	0.88	0.82	0.81	0.83
	2.43	**2.40**	**2.39**	**2.15**
V_1. PKV Rajat	0.73	0.72	0.55	0.66
	1.81	**1.78**	**1.59**	**1.72**
Mean	0.82	0.79	0.72	0.77
	2.11	**2.08**	**2.09**	**2.09**

Bold sign indicate thermal use efficiency in terms of biological yield (kg ha^{-1} °C day^{-1}) at different treatments (2016-17)

Table 3. Influence of sowing dates and genotypes on yield traits of cotton

Treatments	Seed cotton yield plant^{-1} (g)	Seed cotton yield (kg ha^{-1})	Cotton stalk yield plant^{-1} (g)	Cotton stalk yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Lint yield (kg ha^{-1})	B :C ratio
A) Sowing Dates								
D_1- 21st May (20th MW)	62.56	2962	92.33	4351	7550	39.65	1122	2.74
D_1- 15th June (24th MW)	56.85	2618	84.00	4199	6872	38.50	975	2.49
D_1- 15th July (28th MW)	49.00	2207	80.67	3529	6101	36.37	807	2.09
-	**1.23**	**47.50**	**3.24**	**229.62**	**182**	**0.90**	**17.14**	-
CD at 5 %	**3.63**	**139.34**	**9.50**	**673.49**	**535**	-	**50.27**	-
B) Varieties (Genotypes)								
V_1- Ajeet 199 (90 x 30 cm)	87.84	2801	130.33	4105	6866	40.98	1088	2.80
V_1- AKA-8 (60 x 15 cm)	30.94	2753	51.83	4682	7908	34.87	988	2.08
V_1- PKV Rajat (60 x 30 cm)	49.63	2234	74.83	3289	5749	38.67	828	2.45
SE (m)±	**1.23**	**47.50**	**3.24**	**229.62**	**182.72**	**0.90**	**17.14**	-
CD at 5 %	**3.63**	**139.34**	**9.50**	**673.49**	**535.93**	**2.65**	**50.27**	-
Interaction (D x V)								
D_1V_1	95.77	3121	142.50	4625				
D_1V_2	34.60	3134	53.75	4956				
D_1V_3	57.34	2633	80.75	3471				
D_2V_1	87.41	2784	117.50	3742				
D_2V_2	30.14	2676	62.50	5617				
D_2V_3	53.00	2394	72.00	3235				
D_3V_1	80.36	2499	131.00	3949				
D_3V_2	28.08	2448	39.25	3474				
D_3V_3	38.56	1674	71.75	3162				
SE (m)±	**2.14**	**82.28**	**5.61**	**397.71**	**316.48**	**1.56**	**26.96**	-
CD at 5 %	**6.28**	**241.35**	**16.46**	**1166.53**	-	-	-	-
GM	56.14	2596.4	85.66	4026.1	6841.12	38.17	847	2.44

dates influenced lint yield in cotton during the experimentation. Sowing date D_1 (21[st] May) recorded significantly more lint yield (1122 kg ha^{-1}) than remaining sowing dates. Data regarding lint yield was found to be significant with different genotypes. It was observed that the variety Ajeet-199 (V_1) recorded significantly more lint yield (1088 kg ha^{-1}) than all other varieties.

Mean benefit : cost ratio was 2.44. It was observed that the sowing date D_1 (21[st]May) noted significantly more benefit : cost ratio of 2.74 than all other sowing dates. It was observed that the variety Ajeet-199(V_1) registered significantly more benefit : cost ratio of 2.80 than all other genotypes

Similar to this result Patel *et al*. (2016) reported higher seed (3396 kg ha^{-1}) and stalk (5386 kg ha^{-1}) yields of cotton with planting of cotton on 19[th] May over 30[th] May, 9[th] June and 20[th] June. Kaleri *et al.* (2015) observed that cotton sown on 20[th] April proved to be an optimum sowing date and differences in the values of all the traits. In case of varieties, CRIS-134 showed its superiority over TH84/99 and TH8/99 with 116.82 g seed cotton yield plant^{-1} and 2396.55 kg seed cotton yield ha $^{-1}$. Srinivasan *et al*. (2006) also reported highest B:C ratio with VCH-225 hybrid (0.87), followed by PRCHH-5 (0.86), NSPHH-8 (0.83), MECH-184 Bt (0.78) and MECH-12 Bt (0.79). Bhalerao *et al.* (2012) also observed that B:C ratio of pooled data of three year were highest with Bunny Bt as compared to Bunny non Bt cotton.

It is inferred from this study that cotton crop sown under 20 MW (21[st] May) accumulated highest growing degree days (2190^{o}C day) to reach various phenophase, availed higher HTU (13021^{o}C day hour) and more thermal use efficiency with respect to more seed cotton yield with 20 MW (0.82 kg ha $^{-1}$ ^{o}C day $^{-1}$) and also in terms of biological yield. Cotton genotype Ajeet-199 recorded significantly higher seed cotton yield and also high benefit: cost ratio (2.80).

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